SKI YELLOWSTONE
ENVIRONMENTAL STUDY

SKI YELLOWSTONE, INC.
WEST YELLOWSTONE MONTANA

OCTOBER 1973

E R R A T A

SKI YELLOWSTONE ENVIRONMENTAL STUDY

P. 2-8 #17 - the use of the term "snow ranger" implied to U.S. Forest Service responsibility, while in actuality the duty of monitoring conditions in potential snow avalanche areas is assumed by the ski area; Ski Yellowstone, Inc., will assume this responsibility.

Map following P. 3-122 LIMNOLOGY SAMPLING SITES - information contained on this map should be credited to John C. Wright.

Map following P. 3-136 WATER QUALITY SAMPLING SITES - should be credited to J. J. Jezeski.

Map following P. 3-166 VEGETATION INVENTORY map - the last community category under "SHRUB-GRASSLAND (SG)", which is identified as "Snowberry - (Douglas Fir) - Firewood*" should be corrected to "Snowberry - (Douglas Fir) - Fireweed*".

Map following P. 3-184 WILDLIFE INVENTORY map - should be credited to Brent M. Haglund.

P. 3-230 Figure 12, "Artifacts, Corey Springs Collection", was inadvertently omitted during the printing process.

P. 4-1 VISUAL ANALYSIS - section D. "Quality of use" should be corrected to "Quality of views".

Map preceding P. 47 SCENIC RESOURCES: VISUAL SENSITIVITY SUMMARY map - the entire shaded portion should be moved upward so that its lower edge coincides with the shoreline of Hebgen Lake.

P. 5-24 In the second paragraph, it is incorrectly stated that the Yellowstone Airport cannot handle jets.

In the last paragraph, "Kirkwood Ridge development" should be corrected to "Kirkwood Ranch development".

P. 5-29 SOLID WASTE - information concerning refuse disposal in West Yellowstone should be corrected as follows: the town of West Yellowstone has a Special Use Permit from the Forest Service for ten acres of land to be used as a disposal area; this is operated by a private contractor.

POWER AND COMMUNICATIONS - "Falls River Co-op" should be corrected to "Fall River Co-op".

Throughout the study, inconsistent references are made to the distance from West Yellowstone to the Ski Yellowstone site; the distance from the mouth of Red Canyon Creek to West Yellowstone is 13 miles.

ENVIRONMENTAL STUDY

Corrections

Page 5 - 19

V - Socio Economic Impact

School - should read -
has approximately 190 students, grade one to eight - 140 students; grade nine to twelve 50 students.

The school system could absorb an estimated 50% more elementary pupils and [illegible] more high school pupils.

6 7 8 9

Fig. 12. Artifacts from the Corey Springs (Napton) Collection.

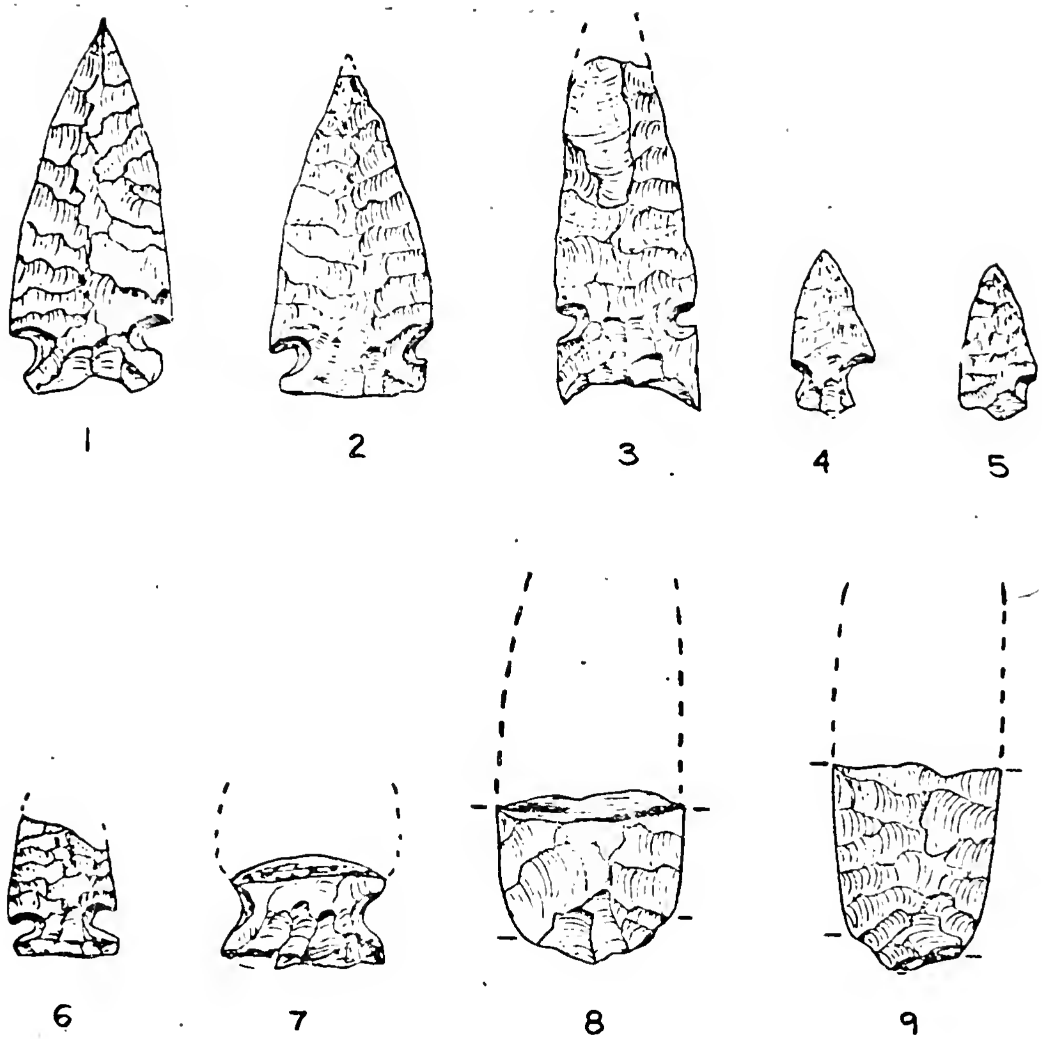
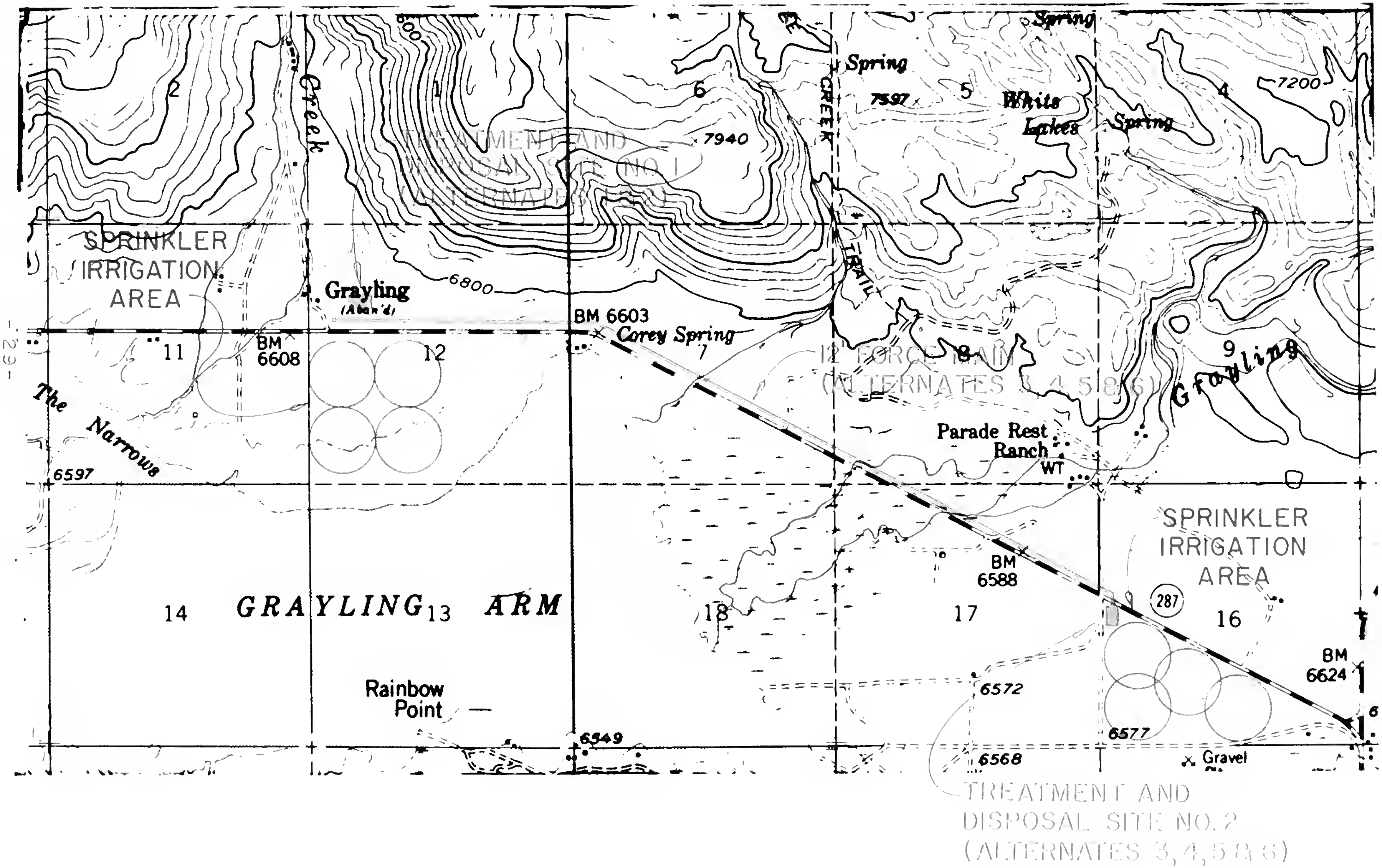


Fig. 12. Artifacts from the Corey Springs (Napton) Collection.



WASTEWATER TREATMENT AND DISPOSAL ALTERNATE SITE LOCATIONS

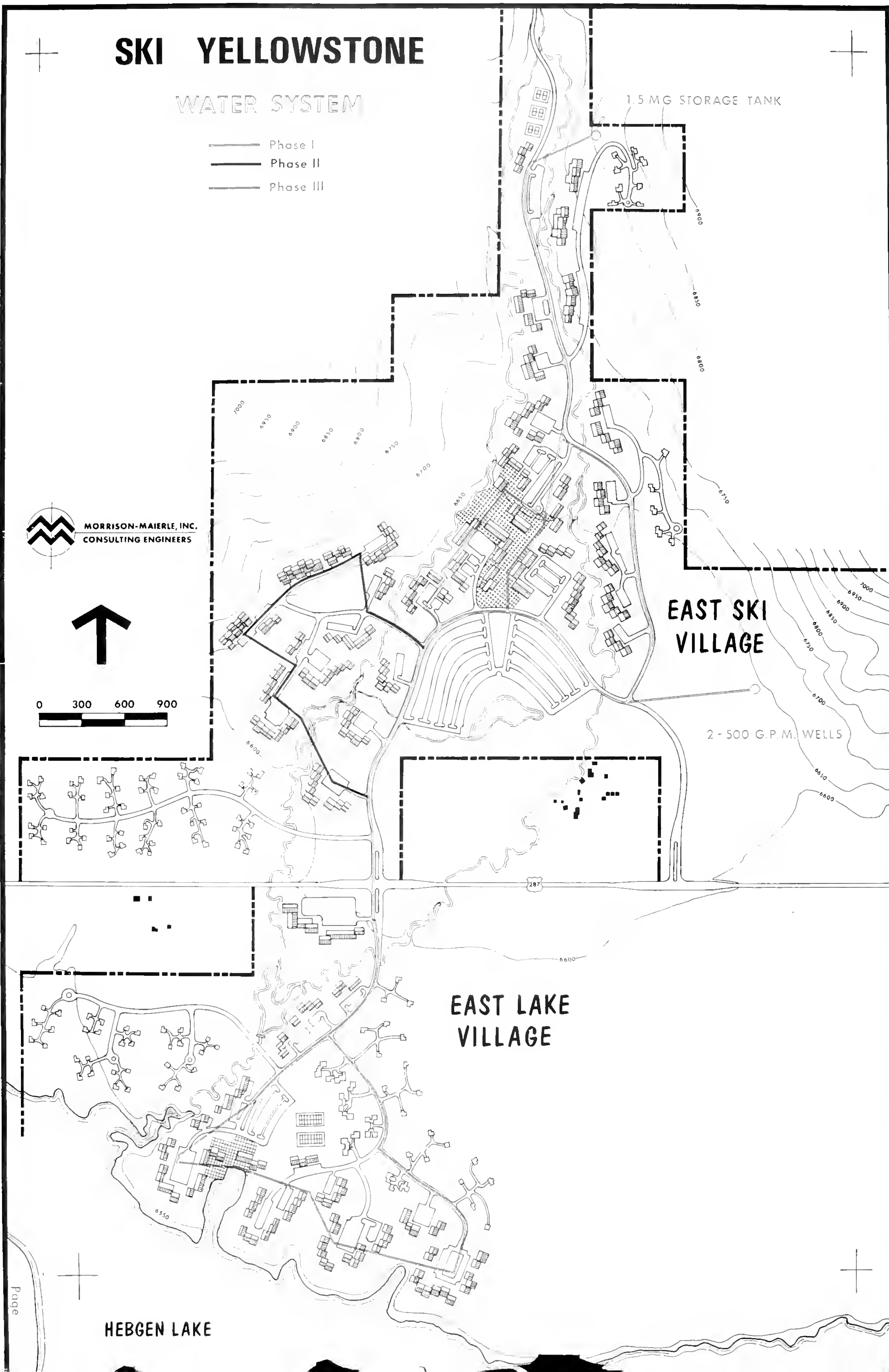

SKI YELLOWSTONE
WATER SYSTEM
Phase I
Phase II
Phase III
MORRISON-MAIERLE, INC.
CONSULTING ENGINEERS
0
300
600
900
1.5 MG STORAGE TANK
EAST SKI
VILLAGE
2 - 500 G.P.M. WELLS
287
EAST LAKE
VILLAGE
HEBGEN LAKE
Page

TABLE OF CONTENTS

	PAGE
ACKNOWLEDGEMENTS	iii
LIST OF MAPS	v
LIST OF FIGURES	vii
LIST OF TABLES	ix
CHAPTER I: INTRODUCTION	
CHAPTER II: PROCESS, FINDINGS, AND EVALUATION	
PROCESS	2-1
FINDINGS AND EVALUATION - Beardsley, Davis Associates, Inc.	2-5
CHAPTER III: BIOPHYSICAL COMPONENTS	
PREFACE TO THE BIOPHYSICAL REPORT - John Montagne, Coordinator, Biophysical Team	3-1
WEATHER AND CLIMATE - Val L. Mitchell	3-5
APPLIED GEOLOGY - John Montagne and Robert H. Page	3-21
SOILS AND SURFICIAL GEOLOGY INVENTORY - Clifford Montagne	3-47
EVALUATION OF HYDROLOGIC CHARACTERISTICS - Donald Alford	3-65
THE LIMNOLOGY OF THE GRAYLING ARM OF HEBGEN LAKE - John C. Wright	3-101
SURVEY OF SURFACE AND GROUND WATER QUALITY - J. J. Jezeski and Gary Bissonette	3-123
PLANT ECOLOGY - Brent M. Haglund	3-137
ANIMAL ECOLOGY - Brent M. Haglund	3-167
ARCHAEOLOGICAL AND HISTORIC RESOURCES: SUMMARY - Leslie B. Davis	3-185

TABLE OF CONTENTS

	PAGE
ACKNOWLEDGEMENTS	iii
LIST OF MAPS	v
LIST OF FIGURES	vii
LIST OF TABLES	ix
CHAPTER I: INTRODUCTION	
CHAPTER II: PROCESS, FINDINGS, AND EVALUATION	
PROCESS	2-1
FINDINGS AND EVALUATION - Beardsley, Davis Associates, Inc.	2-5
CHAPTER III: BIOPHYSICAL COMPONENTS	
PREFACE TO THE BIOPHYSICAL REPORT - John Montagne, Coordinator, Biophysical Team	3-1
WEATHER AND CLIMATE - Val L. Mitchell	3-5
APPLIED GEOLOGY - John Montagne and Robert H. Page	3-21
SOILS AND SURFICIAL GEOLOGY INVENTORY - Clifford Montagne	3-47
EVALUATION OF HYDROLOGIC CHARACTERISTICS - Donald Alford	3-65
THE LIMNOLOGY OF THE GRAYLING ARM OF HEBGEN LAKE - John C. Wright	3-101
SURVEY OF SURFACE AND GROUND WATER QUALITY - J. J. Jezeski and Gary Bissonette	3-123
PLANT ECOLOGY - Brent M. Haglund	3-137
ANIMAL ECOLOGY - Brent M. Haglund	3-167
ARCHAEOLOGICAL AND HISTORIC RESOURCES: SUMMARY - Leslie B. Davis	3-185

CHAPTER IV: LANDSCAPE CHARACTERISTICS AND RECREATION RESOURCES

LANDSCAPE CHARACTERISTICS
- Beardsley, Davis Associates, Inc. 4-1

RECREATION RESOURCES
- Beardsley, Davis Associates, Inc. 4-7

CHAPTER V: SOCIO-ECONOMIC COMPONENTS

MARKET ANALYSIS
- Destination Resort Corporation 5-1

ECONOMIC IMPACT OF THE PROPOSED DEVELOPMENT
- Destination Resort Corporation 5-11

LAND USE ASPECTS
- Beardsley, Davis Associates, Inc. 5-21

URBAN SERVICES
- Morrison-Maierle, Inc. and
Beardsley, Davis Associates, Inc. 5-27

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A study of this magnitude, degree of detail, and complexity could not have been produced without the assistance and work of a great many people and organizations. Among those furnishing information, data, and assistance in the preparation of this study were the personnel of the United States Forest Service - Gallatin National Forest, the Gallatin County Planning Department, the Montana State Highway Department, the State Board of Health, Montana Fish and Game, the Soil Conservation Service, the Supervisor of Yellowstone National Park, the City Council and Chamber of Commerce of West Yellowstone, and interested citizens.

The following investigators participated directly in the gathering of information and compilation and evaluation of results which appear in this report:

MSU Dr. John Montagne, Project Director, Biophysical Team - Bedrock Geology
Beardsley, Davis Associates, Inc., Project Coordinator - Scenic Resources, Recreation, Land Use, and Transportation
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Gary Bissonette - Microbiology
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Destination Resort Corporation - Marketing and Economic Evaluation
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MSU Dr. Val L. Mitchell - Climatology
MSU Clifford Montagne - Soils and Surficial Geology
Morrison-Maierle, Inc. - Utilities
Robert H. Page - Bedrock Geology
MSU Dr. John C. Wright - Limnology

LIST OF MAPS

On-Site Study Area

Off-Site Study Area

Resultant Development Impact

Bedrock Geology Inventory

Bedrock Geology Development Limitation Zones

Soils-Surficial Geology Inventory

Soils-Surficial Geology Development Limitation Zones

Hydrology Development Limitation Zones

Limnology Sampling Sites

Water Quality Sampling Sites

Vegetation Inventory

Wildlife Inventory

Plant and Animal Ecology Development Sensitivity Zones

Archaeology Inventory

Archaeology Development Sensitivity Zones

Scenic Resources Visual Analysis

Scenic Resources Visual Sensitivity Summary

Recreation Resources Existing Recreation - Inventory

Recreation Resources Future Recreation - Prediction

Subdivision Locations

LIST OF FIGURES

Chapter II: STUDY PROCESS, FINDINGS, AND EVALUATION

PROCESS

Figure 1....................................On-Site Study Area
Figure 2..................................Off-Site Study Area
Figure 3..................Environmental Impact Potential Form

Chapter III: BIOPHYSICAL COMPONENTS

WEATHER AND CLIMATE

Figure 1.........Generalized Nighttime Airflow from Red Canyon
Figure 2...........Generalized Daytime Airflow from Red Canyon

APPLIED GEOLOGY

Figure 1.........................Bedrock Geology Inventory Map
Figure 2..................Bedrock Geology Limitation Zones Map

EVALUATION OF HYDROLOGIC CHARACTERISTICS

Figure 1............................Red Canyon Creek Watershed
Figure 2..........................Topography of the Watershed
Figure 3..........................Sub-basins of the Watershed
Figure 4.....................Long Profile of Red Canyon Creek
Figure 5...................Hypsometric Curve of the Watershed
Figure 6..................Slope Orientations in the Watershed
Figure 7........................Hydrogeology of the Watershed
Figure 8.................................Regional Hythergraph
Figure 9..........................Isohyetal Snow Pack Pattern
Figure 10....................Basin Snowcover Pattern - 30 Days after Initiation of Spring Melt
Figure 11....................Basin Snowcover Pattern - 45 Days after Initiation of Spring Melt
Figure 12........................Precipitation Return Periods
Figure 13.................."Twenty-five Year" Flood Discharge vs. Watershed Surface Area
Figure 14..........Specific Discharge vs. Annual Precipitation

SURVEY OF SURFACE AND GROUND WATER QUALITY

Figure 1............................Total and Fecal Coliforms
Figure 2.......................................Total Hardness
Figure 3..Sulfate
Figure 4.......................................Orthophosphate
Figure 5..Nitrate
Figure 6..Ammonia
Figure 7...Chloride

Chapter III: BIOPHYSICAL COMPONENTS (Cont.)

ARCHAEOLOGICAL AND HISTORIC RESOURCES: SUMMARY

Figure 1......................Site and Find Spot Distribution
Figure 2............................Archaeology Inventory Map
Figure 3.........Archaeology Development Sensitivity Zones Map
Figure 4............Colluvial-Alluvial Terrace - Y-Bother Site
Figure 5..............................Hearth at Peterson Site
Figure 6....................Excavations at Upper Terrace Site
Figure 7................Stream-Cut Terrace at Main Cabin Site
Figure 8...........Projectile Points, Rainbow Point Collection
Figure 9...................Knives I, Rainbow Point Collection
Figure 10..................Knives II, Rainbow Point Collection
Figure 11...............End Scrapers, Rainbow Point Collection
Figure 12.................Artifacts, Corey Springs Collection
Figure 13.................Artifacts, Corey Springs Collection
Figure 14.........Artifacts, Red Canyon Fan-Narrows Collection
Figure 15.........Mounded Fire-Cracked Rock; the Narrows, 1960
Figure 16...........Beach and Docks Exposed; the Narrows, 1960
Figure 17...Cultural Bone
Figure 18...............Hydration Dated Obsidian Specimens, I
Figure 19...............Hydration Dated Obsidian Specimens, II
Figure 20..........Hydration Frequency and Cultural Chronology

Chapter IV: LANDSCAPE CHARACTERISTICS AND RECREATION RESOURCES

VISUAL ANALYSIS

Figure 1...................Scenic Resources: Visual Analysis
Figure 2.........Scenic Resources: Visual Sensitivity Summary

RECREATION RESOURCES

Figure 1..................Existing Recreation - Inventory Map
Figure 2..................Existing Recreation - Prediction Map

Chapter V: SOCIO-ECONOMIC COMPONENTS

LAND USE ASPECTS

Figure 1...............................Subdivision Locations

LIST OF TABLES

Chapter III: BIOPHYSICAL COMPONENTS

WEATHER AND CLIMATE

Table 1........Temperature Estimates - Red Canyon Village Site

Table 2..................Percent Days with Maximum Temperature At or Below Selected Values
Table 3..................Percent Days with Minimum Temperature At or Below Selected Values
Table 4..............Precipitation Estimates - Red Canyon Area
Table 5..............Number Days with Measurable Precipitation
Table 6.........................Cloud Cover - Red Canyon Area
Table 7.....................................Evapotranspiration

THE LIMNOLOGY OF THE GRAYLING ARM OF HEBGEN LAKE

Table 1.........................Percentage Light Transmission
Table 2...Turbidity
Table 3...Temperature
Table 4..Oxygen
Table 5..pH
Table 6.................................Free Carbon Dioxide
Table 7..Conductivity
Table 8...Total Hardness
Table 9.......................................Calcium Hardness
Table 10.....................................Total Alkalinity
Table 11..Calcium
Table 12..Magnesium
Table 13...Sodium
Table 14..Potassium
Table 15..Bicarbonate
Table 16...Chloride
Table 17..Sulfate
Table 18...Fluoride
Table 19...Silica
Table 20...........................Ortho Phosphate Phosphorus
Table 21......................................Ammonia Nitrogen
Table 22......................................Nitrate Nitrogen
Table 23..Chlorophyll A
Table 24..Chlorophyll A
Table 25.........................Surface Phytoplankton Volume
Table 26..Zooplankton
Table 27...........................Stream Insect Standing Crop

Chapter III; BIOPHYSICAL COMPONENTS (Cont.)

PLANT ECOLOGY

Table 1.............Coniferous Forest: Douglas Fir - Snowberry
Table 2............Coniferous Forest: Douglas Fir - (Subalpine Fir) - Snowberry
Table 3.............Coniferous Forest: Douglas Fir - Whitebark Pine - Balsamroot
Table 4..............Coniferous Forest: Subalpine Fir - Grouse Whortleberry
Table 5...........Coniferous Forest: Subalpine Fir - Whitebark Pine - Grouse Whortleberry
Table 6.............Coniferous Forest: Lodgepole Pine - Grouse Whortleberry
Table 7...........Coniferous Forest: Englemann Spruce - Grouse Whortleberry
Table 8...........Coniferous Forest: Englemann Spruce - Willow
Table 9..............................Deciduous Forest: Aspen
Table 10............Shrub Community: Big Sagebrush - Snowberry
Table 11..............................Shrub Community: Willow
Table 12.........Shrub-Grassland: Big Sagebrush - Idaho fescue
Table 13................Shrub-Grassland: Big Sagebrush - Hoary Sagebrush - Idaho fescue
Table 14...........Shrub-Grassland: Big Sagebrush - Wheatgrass
Table 15...........Shrub-Grassland: Big Sagebrush - Balsamroot
Table 16...........Shrub-Grassland: Snowberry - (Douglas Fir) - Fireweed
Table 17............Grassland: Kentucky bluegrass - Timothy - Smooth brome
Table 18..............................Grassland: Idaho fescue
Table 19.............................Forb Community: Bluebell
Table 20.............Forb Community: Coneflower - HorseMint - Cow Parsnip
Table 21...............................Rush-Sedge: Rush-Sedge

WILDLIFE ECOLOGY

Table 1.....................Hebgen Area Species List: Mammals
Table 2.................Hebgen Area Species List: Land Birds, Non-game and Non-prey
Table 3...............Hebgen Area Species List: Birds of Game and Prey

ARCHAEOLOGICAL AND HISTORIC RESOURCES: SUMMARY

Table 1.........Archaeological and Historic Sites Inventory, I
Table 2........Archaeological and Historic Sites Inventory, II
Table 3.......Archaeological and Historic Sites Inventory, III
Table 4.............Frequency Distribution of Lithic Varieties
Table 5.......Absolute Ages of Archaeological Obsidian Samples

Chapter IV: SOCIO-ECONOMIC COMPONENTS

MARKET ANALYSIS

Table 1..........Projected Growth in the National Skier Market
Table 2..........Projected Skier Days and Total Winter Visitor Days at Ski Yellowstone
Table 3..................Visitors to Yellowstone National Park
Table 4........................Analysis of Recreation Visitors in the West Yellowstone Area
Table 5..........Projected Summer Visitors to West Yellowstone
Table 6..........Winter Visitor Days and Sleeping Capacity and Skier Capacity Required at Ski Yellowstone

ECONOMIC IMPACT OF THE PROPOSED DEVELOPMENT

Table 1........................Personal Income by Major Sources
Table 2........................Computation of Income Multiplier
Table 3...................Projected Direct and Indirect Income Resulting from Ski Yellowstone

LAND USE ASPECTS

Table 1..........Subdivisions Located in West Yellowstone Area

I. Introduction

INTRODUCTION

Ski Yellowstone is a recreation community proposed for the Mt. Hebgen area near Hebgen Lake, Montana. The resort is to be located adjacent to U. S. Highway 287 about twelve miles northwest of West Yellowstone, Montana, which is the west entrance to Yellowstone National Park. The 4-Seasons, Destination Resort will include a major ski area on the slopes of Mt. Hebgen as well as a lake village on Hebgen Lake providing both winter and summer recreation for several thousand persons. Trails and lifts for skiing, as well as a mountain restaurant, are planned for Mt. Hebgen, with the gondola lift facilities being used in summer for sightseeing. The base area village will provide accommodations, shops, restaurants, recreation facilities including a marina on Hebgen Lake, and an environmental education facility. A total ultimate development with 5500 beds for visitors and employees residing in the area, and for 1000 additional day skiers, is planned.

The site for the proposed development was chosen on the basis of a number of locational factors and favorable existing conditions, as outlined below:

1) The site is located in close proximity to Yellowstone National Park. Yellowstone attracted 2,246,428 visitors in 1972, with 692,901 of these entering the park at its west entrance, which is twelve miles from the Ski Yellowstone site.

2) Ski Yellowstone is located in the Madison River Canyon, which is travelled by 200,000 to 300,000 visitors in the summer months.

3) Mt. Hebgen is a very good skiing mountain, with a total vertical rise of 2,000 feet, trails for all abilities, and the potential for excellent cross-country skiing and summer recreation activities.

4) Mt. Hebgen possesses excellent snow, wind, and weather conditions for skiing.

5) Hebgen Lake, which borders the Ski Yellowstone development site, provides the potential for water-related summer recreation activities.

6) The ownership characteristics of land in the vicinity of the proposed development - largely Gallatin National Forest lands - guarantee relatively limited future urbanization in the area surrounding the project site.

7) The National Park Service has initiated a policy which encourages future development of overnight visitor accommodations outside, and within one hour's driving distance, of Yellowstone National Park.

The following environmental study was undertaken in order to ascertain possible environmental effects of, or constraints on, the proposed Ski Yellowstone development. Included is an identification and assessment of both possible on-site environmental impacts of the project and possible off-site impacts on the immediate surrounding area and the community of West Yellowstone.

The information contained in this report is to be made available to the U.S. Forest Service for use in its preparation of an Environmental Impact Statement for the project.

II. Study Process, Findings, and Evaluation

PROCESS

AIMS AND SCOPE

The principal objectives of the Ski Yellowstone Environmental Study include the preparation of an inventory of environmental resources, the determination of the impacts of proposed ski area alternatives on these resources, and the development of ways in which any negative impacts may be mitigated. Scientists and consultants, as well as federal, state, and local agencies and general citizen organizations, provided source material and input for the study.

The resources inventories include descriptions of bio-physical features of the site, such as topography, soils, surface and sub-surface geology, climatic factors, hydrology, and landscape characteristics, as well as descriptions of the presence, distribution, ecological role, and relative uniqueness of value of terrestrial and aquatic flora and fauna of the project area. Off-site impact considerations such as land use, economic aspects, utilities, community facilities, and transportation, are also investigated.

As one ultimate aim of the study is to generate information which can be used to predict and evaluate environmental effects of, and constraints on, the proposed Ski Yellowstone development, it was necessary to devise a means for handling the great amount of detailed base information generated. A method was developed for summarizing practical applications and implications of the data and consolidating them into a more concise form.

On-site and off-site areas of concentration were defined, with the on-site studies including components of a bio-physical (i.e. bedrock geology, soils and surficial geology, hydrology, climatology, plant ecology, wildlife ecology, water quality, limnology, archaeology)and scenic-recreational nature. These studies focus on the area surrounding the proposed development site, which was divided into two portions as shown in Figure 1: a Primary Study Area, that portion of the region to be most directly affected or altered by the development (i.e. ski slopes, village site); and a Secondary Study Area, in which more indirect effects might be felt.

The off-site studies pertain to socio-economic components (i.e. economic, employment, housing, finance, land use, transportation, utilities) of the environment which may be affected by or may affect Ski Yellowstone. As off-site impacts will generally be limited to privately-owned lands within the Gallatin National Forest, West Yellowstone, and major transportation corridors such as State Highways #191 and #287, studies emphasize these areas, as indicated on Figure 2, with detailed study focusing specifically on West Yellowstone and its immediate surrounding area. Particular emphasis is placed on the Ski Yellowstone development's potential relationship to these areas.

RESEARCH METHODS

Bio-physical aspects of the Primary and, where appropriate, the Secondary, Study Areas were inventoried and studied in the field during the summer months. Studies were made of the various components to determine existing characteristics, areas of possible inherent limitations to development, and potential impacts of the development on the environment. Individual detailed reports of findings for each component are included in this report. Each investigator also estimated environmental constraints, impacts, and possible mitigation procedures, as outline in the methodology section below.

Landscape characteristics and recreation resources were inventoried and, where appropriate, evaluated with respect to Ski Yellowstone. For all on-site studies, information was mapped where possible. Existing conditions of socio-economic components were assessed, and the potential relationship of these to Ski Yellowstone, and vice versa, evaluated. In all cases, both positive and negative development effects were considered.

METHODOLOGY

In order to facilitate interpretation and evaluation of the field data collected, the following method was used to summarize findings. The first step involved "Early Warning Input." Before making detailed studies, each field investigator attempted to assess areas or conditions that might cause problems as far as development was concerned. These conditions were then taken into consideration in the preliminary planning of the development.

In addition to presenting the results of their studies in detailed reports and inventory maps, investigators were asked to categorize areas of potential limitation or sensitivity to development, and to map these where possible. Categories of "potential severe long-term impact," "potential moderate long-term impact," and "potential significant short-term impact" were suggested, to be followed where applicable. Each investigator provided a description of his interpretation of the categories he used as they pertained to his component study. Since all areas which the investigator might rank in a potential impact category would not be placed in that category because they possessed identical characteristics of limitation or sensitivity, each was identified on the map as to the type of limitation or sensitivity which it possessed. All of these limitation/sensitivity maps were then compiled into a Composite development limitations/sensitivity map.

Environmental Impact Potential forms (Figure 3) provided a means by which pertinent information concerning each type of limitation or sensitivity, and procedures for mitigating impact, could be summarized. Each field investigator attempted to assess potential development impact by comparing the proposed development plan for Ski Yellowstone with his limitations/sensitivity map. Each type of conflict area was treated individually on an Environmental Impact Potential form, and assessed as to degree of potential impact, sphere of influence of this impact, and resulting environmental costs or benefits. Also on the Environmental Impact Potential form, procedures for mitigating the impacts were given, potential impact assuming these processes were implemented

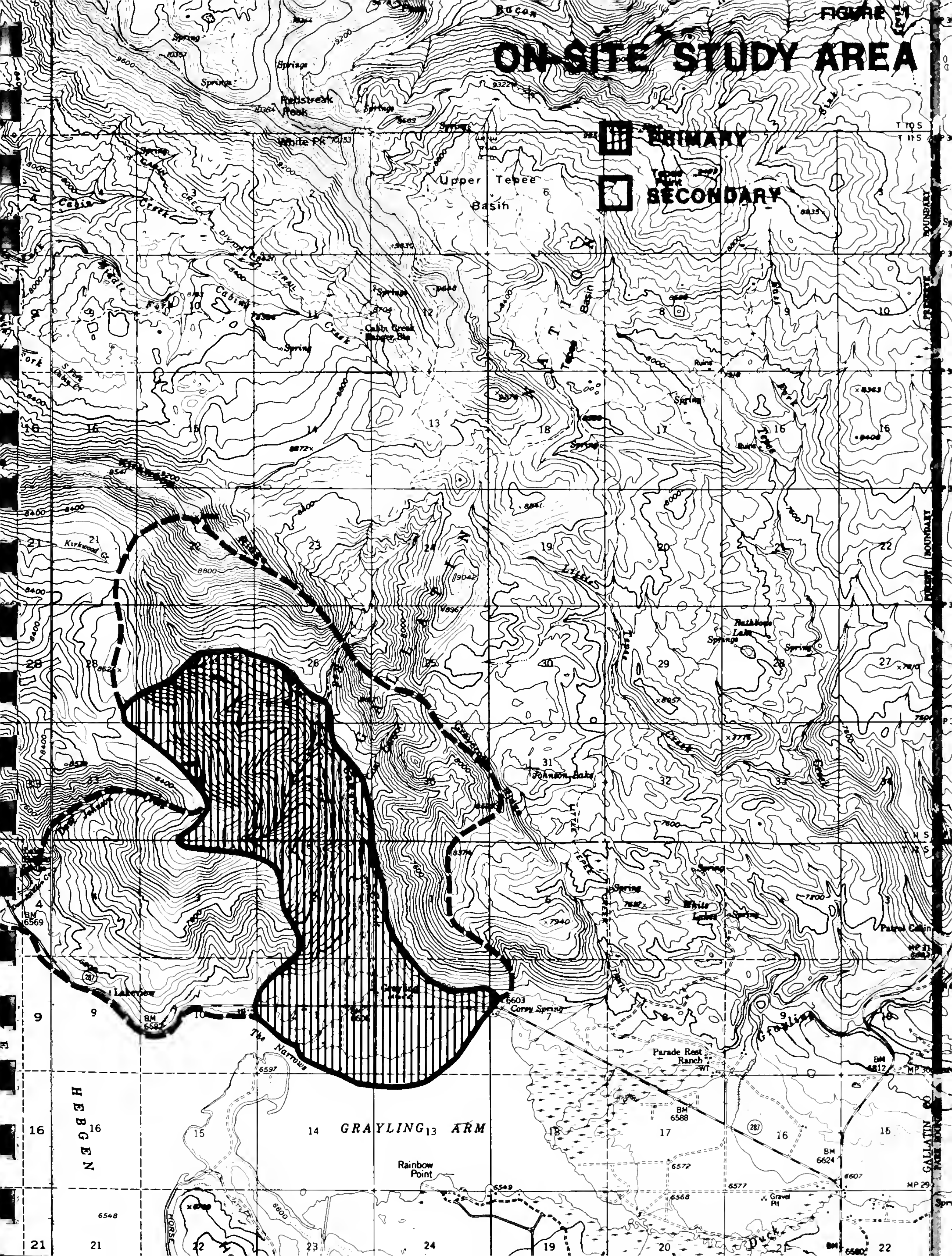


FIGURE 1
ON-SITE STUDY AREA
PRIMARY
SECONDARY
Upper Tepee Basin
White Pk
Redstreak Peak
Cabin Creek
Kirkwood Cr.
Little Tepee
Johnson Lake
Rathbone Lake
White Lakes
Patrol Cabin
Corey Spring
Parade Rest Ranch
The Narrows
HEBGEN
GRAYLING ARM
Rainbow Point
Gravel Pit

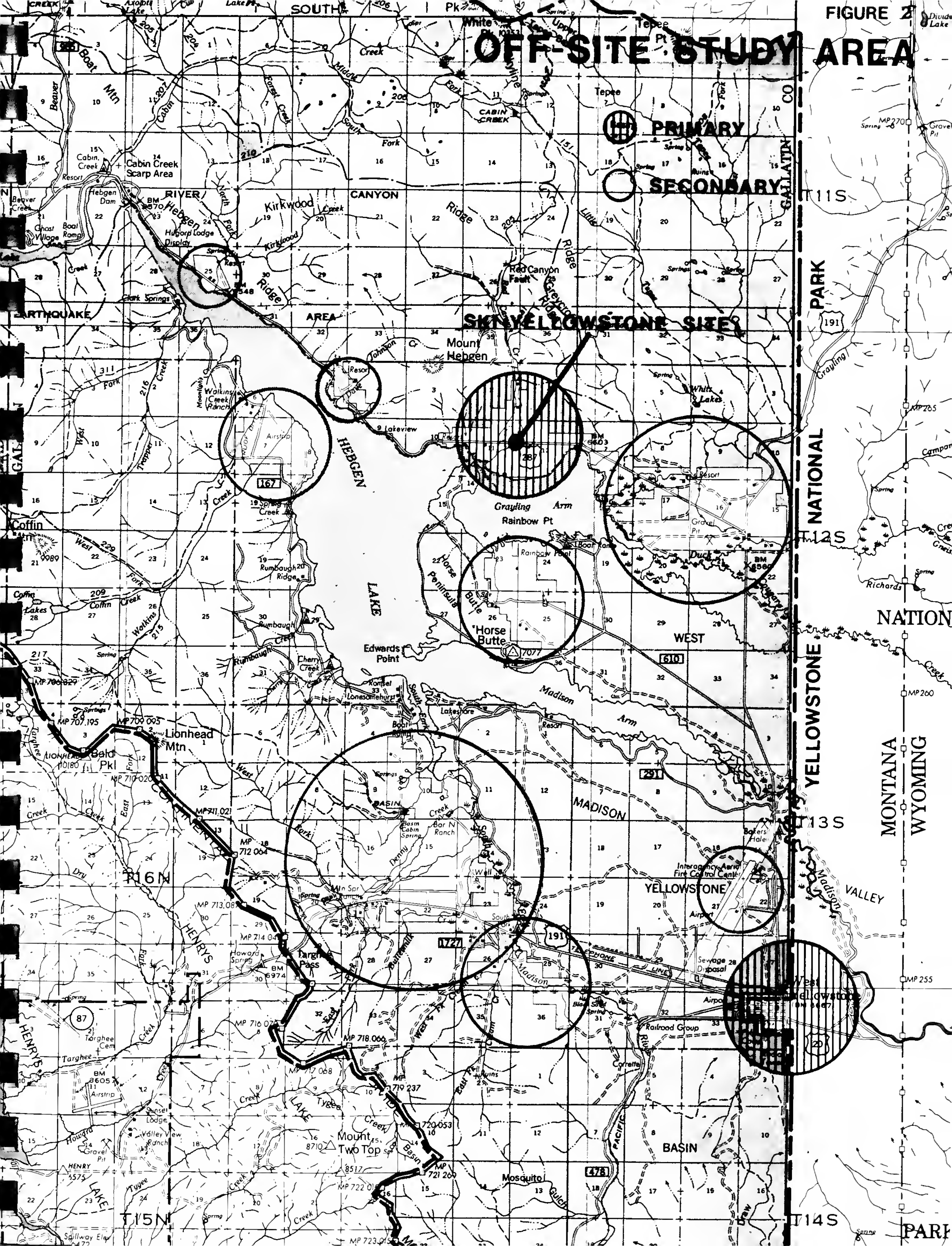


FIGURE 2
OFF-SITE STUDY AREA
PRIMARY
SECONDARY
SKI YELLOWSTONE SITE
HEBGEN LAKE
Grayling Arm
Rainbow Pt
Horse Butte
Edwards Point
Madison Arm
Mount Hebgen
Kirkwood
CANYON
RIVER
Hebgen Dam
Cabin Creek Scarp Area
EARTHQUAKE
AREA
Lionhead Mtn
Targhee Pass
Mount Two Top
BASIN
MADISON
WEST
YELLOWSTONE
Interagency Aerial Fire Control Center
West Yellowstone
Railroad Group
Sewage Disposal
YELLOWSTONE NATIONAL PARK
MONTANA
WYOMING
Madison VALLEY
T11S
T12S
T13S
T14S
T16N
T15N

Area-type (#__): ____________ ENVIRONMENTAL IMPACT POTENTIAL Component: ____________

Negative [] *Positive []

Potential development impact (from maps)	Sphere of influence of impact			Significant environmental costs/benefits		Environmental constraints/ Design criteria	Potential impact after mitigation	Resultant environmental costs/benefits
-1,-2,-3 *+1,+2,+3	1° Area	2° Area	Gall. Co.	Possible effects - this component	Resultant effects on other components	[Mitigation procedures]	-3 to +3	(after mitigation)

FIGURE 3

was assessed, and an explanation was given of the extent and type of resultant impacts, if any, after mitigation.

Taking the above mitigation procedures into account, and assuming their implementation wherever possible, a final assessment of resultant development impact was made. A summary map and list of mitigation procedures assumed to be followed were prepared, illustrating remaining zones of potential impact, if any. These procedures are then to be followed as closely as possible in the final planning process in order that a minimum of adverse impacts may result.

F I N D I N G S   A N D   E V A L U A T I O N

Beardsley, Davis Associates, Inc.

INTRODUCTION

The purpose of this section is to provide a means to consolidate all of the information contained in the following reports of potential environmental impact of the proposed Ski Yellowstone development. An attempt is also made to summarize the practical application of the data as it relates to developing this specific site. Each investigator of on-site components made an assessment of possible impact of the project on his area of study. This information was analyzed and utilized to attempt to predict the actual net impact potential of the development. Mitigation procedures suggested by the investigators to minimize or eliminate potential impacts were assumed to be followed, wherever possible, and then an estimate was made of the extent and magnitude of remaining impacts which could not be completely mitigated. These are summarized in the Map of Resultant Development Impact, and the mitigation procedures are explained which were assumed to be followed in the planning and construction of the development as analyzed.

COMPOSITE OF POTENTIAL IMPACTS

In an attempt to summarize areas of potential limitation, or sensitivity to, development, a Composite map was made showing all areas which appear on any of the component limitation or sensitivity maps. Several potential limitations or sensitivities to development exist which were not mappable, and therefore did not appear on the Composite map. These include the following:

1) Air Pollution - a problem could exist during very cold periods of short duration in which temperature inversions persist throughout the day, if a clean source of heat is not used, and unlimited fireplace use occurs.

2) Construction Period Effects - an increase in dust in the air will occur during the actual time of construction, and an increase in the sediment load of the creek may also occur at this time.

3) Air Quality - an odor problem could occur if the sewage treatment plant is located in such a way that prevailing winds blow across it and through the village. Location on the eastern portion of the alluvial fan would minimize this potential problem.

4) Ground Shaking - shaking associated with local seismic activity could occur throughout the area. To minimize this potential problem, structures should be built to meet earthquake Zone 3 requirements of the Uniform Building Code.

RESULTANT DEVELOPMENT IMPACT

MAP OF RESULTANT DEVELOPMENT IMPACT

In compiling the Resultant Development Impact map, all areas in which limitations for, or sensitivities to, development had appeared on any of the individual components' maps were considered. These areas were then compared with the proposed plan for the development. Any areas in which potential conflicts occurred were further examined. Areas which appeared on a limitations or sensitivities map, but in which no actual development was planned, were judged to therefore have little or no potential impact with respect to the planned development.

In the case of areas which were defined on a component's map as having potential limitation for or sensitivity to development, and in which actual development appeared on the preliminary plan, the investigator's report and Environmental Impact Potential forms (summarized in Figure 3) were consulted to determine the extent, type, and magnitude of the potential impact, and to determine what, if any, mitigation procedures could be followed in order to eliminate or minimize the effect. A judgment was then made concerning whether or not the mitigation procedure could be followed, and to what extent this would mitigate the impact. This potentially "mitigated impact" is shown on the Resultant Development Impact map.

It should be noted that "development impact" was judged on the basis of both potential impact that the environment might have on the development and also impacts that the development could have on the environment. A judgment was made as to the relative severity of impact of the vastly different components which were being considered in the study, as these impacts relate to the feasibility and practicality of developing this site.

MITIGATION PROCEDURES

As stated above, many of the impacts shown on the component development limitations or sensitivity map have the potential of being partially or wholly mitigated. By assuming that the mitigation procedures suggested by investigators were followed wherever possible, the "Resultant Development Impact" map was prepared. It can be seen that most of the areas identified by investigators as being zones of potential limitation for, or sensitivity to, development can be eliminated from this final map if the following mitigation procedures are followed:

1) Fireplace use is restricted to prevent air pollution during potential short term periods of temperature inversion.

2) Buildings are engineered for Zone 3 construction and design in accordance with the Uniform Building Code to prevent damage during limited seismic activity.

3) An archaeologist is consulted in the case of excavation in known or suspected archaeological or historical site areas.

4) The west primary channel of the creek is designed for flood hazard mitigation, but water is not allowed to flow in it at all times, in order to prevent valuable artifacts from being disrupted.

5) Spray irrigation, not septic tank disposal, is utilized on the alluvial fan, because of soil drainage limitations.

6) Detailed investigations are made of the extent and depth of the lower sandy layer at the top of Mt. Hebgen, and it or the limestone frost rubble is utilized for the sewage system there, if possible.

7) Determination is made of the exact location of the active crack near the top of Mt. Hebgen along the lift A line, and lift tower foundations are not located there.

8) On-site investigations are made of the lift G line where it passes near a slide zone, and lift tower foundations are not located in this zone.

9) On-site investigations are made during design and construction of lift line G and the base of lift J where they pass through inactive slide zones; drainage facilities are installed in wet areas and water conditions are monitored.

10) On-site inspections are made during design and construction of lift I where it passes through the area of wet, clayey soil; drainage is installed and proper foundations are prepared in order to prevent initiation of instability by construction.

11) Proper engineering construction preparation is utilized, such as drainage and gravel foundation beds, in order to prevent damage to the foundations of the lift towers of lifts N, I, H, and K, where they pass through zones of high shrink-swell and frost heave potential.

12) As much understory as possible is left on slopes, diversion ditches are constructed if needed, and mulch is applied to areas of steep sandy slopes to be cleared for ski trails and lift lines D and A, in order to prevent erosion.

13) Proper engineering design procedures are utilized in constructing lift towers of lifts O, P, N, M, L, J, G, H, D, C, E, and B, where they pass through areas with shallow soil depth to bedrock.

14) Headgates or small concrete structures are constructed in Red Canyon above the creek fork; building is not done in the primary creek channels; the two main primary stream channels are kept open at all times for flood control; channel gradient and geometry is not substantially modified; and, perhaps, a small amount of engineering work in the area of bifurcation of the two main channels is done, to prevent channelized runoff flooding and sheet flooding on the alluvial fan.

15) Nothing, except possibly a marina facility, is built along the shoreline of the alluvial fan in the zone of possible permanent submersion by seiche.

16) Lift K base is moved up above the dry fork valley (to the south of the valley) and the area monitored for possible rockfall and avalanche danger.

17) Ski touring trails are kept out of the dry creek valley below Kirkwood Ridge, trails are maintained and packed, and a snow ranger is used to monitor conditions in potential snow avalanche areas.

18) The base of lift J is moved away from the zone of active mass movement and rockfall. (Moved about fifty yards uphill.)

19) Lift towers are located wherever possible away from shale zones on lift lines A, B, C, D, G, I, J, M, and N, to prevent downslope creep. If lifts must be located on shale (potential mass movement) zones, it should be ensured that proper drainage exists around the base of lift towers, and the entire zone should be well drained except in cases in which it is desirable to keep the shale damp to prevent it from completely drying out.

20) Sites are investigated before a mountain restaurant and lift foundations of lifts A, C, H, G, and K are constructed in order to determine potential limestone collapse zones on the top of Mt. Hebgen. No buildings are constructed in active collapse sites, and holes in this zone are grouted, if necessary.

21) Ground water tracer studies are made before sewage drainfields are located on the top of Mt. Hebgen in a possible limestone solution collapse zone, in order to prevent contamination of ground water systems.

22) Foundations of lifts N and O are moved, if easily feasible, in order to avoid zones in which there is a (extremely low) possibility of faulting offset.

23) As much open space as possible is left in the form of parking lots, parks, etc., and no housing is constructed of greater than two story height, in the low risk zone of possible fault projection.

24) Adequate boat toilet sewage disposal facilities are ensured, in order to prevent water pollution due to inadequate disposal techniques.

25) To prevent an increase in turbidity and sediment in the creek during runoff periods and to prevent erosion of stream banks, settling ponds are provided on the creek during construction and for a short time thereafter; roads are properly graded and promptly revegetated, as are ski runs and other areas, to minimize erosion.

26) Helicopter transport of materials and care during construction is utilized when placing towers of lift C on steep arid slopes with scanty vegetation, and reseeding and mulching are done when construction is completed.

27) Construction and summer operation of lifts is delayed until after elk calving is over.

28) Ski trails through the stand of lodgepole pine are made as small as possible, or the pines are removed, to prevent windfall danger during high winds.

29) Building does not take place within fifty feet of stream banks.

30) To minimize impacts on vegetation, trampling-resistant plant species are planted in the mountain restaurant area and lift terminal areas, trails are designed around the mountain restaurant to concentrate activity, construction-damaged areas are rehabilitated, summer activity is directed away from scantily-vegetated, thin-soiled areas as much as possible, and vehicular and construction activity is regulated to avoid wet soil conditions.

31) Sewage treatment plant is built on the eastern portion of the alluvial fan, in order to prevent prevailing winds from possibly carrying odors into the village area.

IMPACT REMIANING AFTER MITIGATION

Several areas of potential impact to, or resulting from, development appear on the following map of Resultant Development Impact. For these areas, mitigation procedures are either unavailable or they do not serve to totally eliminate the impact potential even when they are followed. These remaining areas of potential impact are described below.

IMPACT TYPES

G1 - Possible downslope movement of lift line G.

At the present time, lift line G is planned to be built on a zone identified as being a landslide area. Unless the alignment of the lift is altered to avoid this zone entirely, a limitation will remain. This may be minimized by building the base station of the lift away from the axis of the slide, draining foundations and the surrounding material effectively, and monitoring the area for creep. If these procedures are followed, the limitation will still exist, but in minimal form.

G2 - Potential for short-term flooding at times of major local seismic activity.

A potential exists along the shoreline of the alluvial fan, up to a maximum of thirty feet vertically above the level of the lake, for flooding of short duration during a major local earthquake. Building which is done in this strip should be engineered and constructed in such a manner that short term flooding would have little effect on structures.

E1 - Disturbance to elk caused by lifts constructed on and adjacent to elk winter range: may cause elk to move into less desirable range - possible eventual decline in elk herd size from the present herd of at least twenty.

Although presenting a severe potential impact to the elk involved, in relation to the region in question, and to the proposed development, the potential development impact would seem to be more moderate in nature. The developer plans to prohibit skiing on the southernmost and western slopes of Mt. Hebgen, and to attempt to establish this area as an enclave for the elk which might move into it from the area where lifts and trails are planned, thus impinging on their winter range. Snowmobiles will also be eliminated from the development and mountain area around the project, and this should have the effect of eliminating a source of disturbance which now exists.

E2 - Disturbances in a low density (3-5) moose wintering area: probable eventual small decline and loss of several moose.

Again, although the impact potential on the moose themselves is designated by the consultant in this area as severe, when looked at from the viewpoint of the region,actual development impact in the on-site area seems to be more of a moderate nature. (Grayling Creek Delta is defined as being a much more important moose wintering, and calving area, and Yellowstone National Park and the Gallatin National Forest both serve as the major wildlife areas for the moose.) The prohibition of snowmobiles in this area may help to offset the effects caused by an increase in the absolute number of people to be using the site. The developer has also stated that attempts will be made to acquire the marshland of the Grayling Creek Delta which is not now in their ownership, and to keep that land which they already own, along with any additional acquisitions, in a natural state in order that the moose may continue to use this area. Perhaps, this land would be deeded to the Forest Service for management. Construction or lift operation will be suspended during times of migration.

E3 - Lifts placed in elk calving area: elk may not calve in this area.

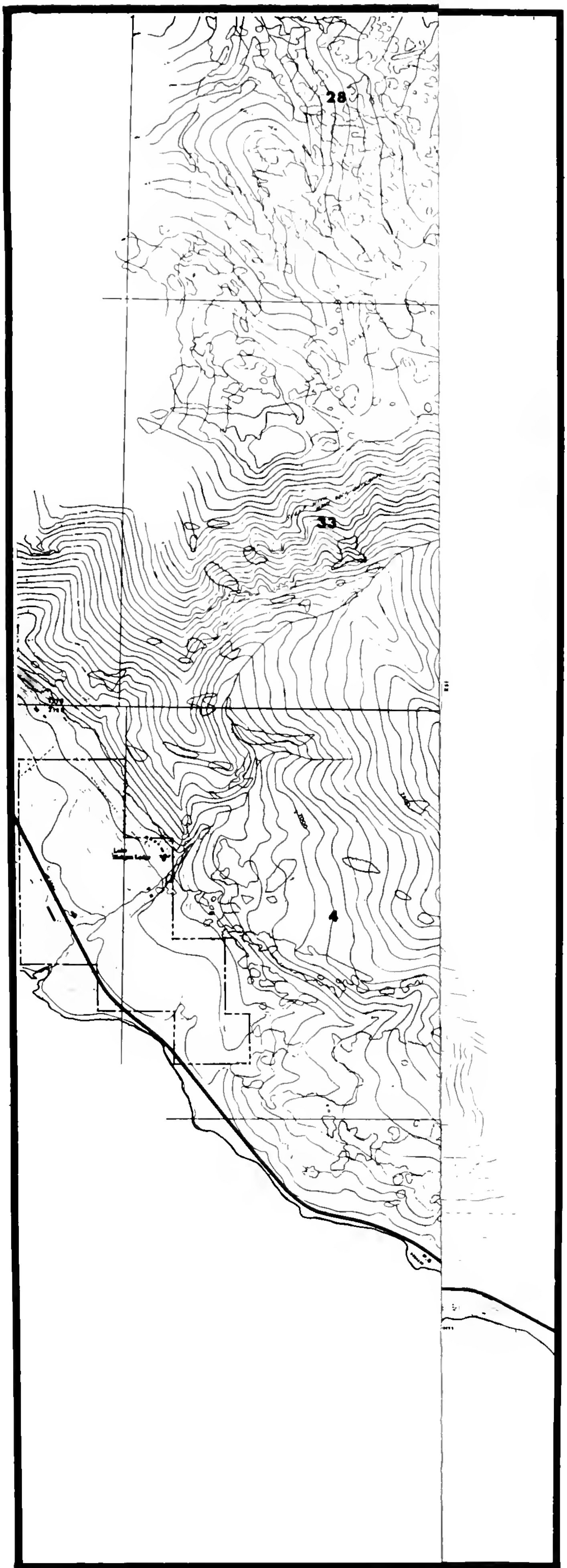
All possible procedures are planned to be followed in order to keep a negative effect from being felt by the elk which are calving in this area. Construction proceedings and any summer operation of lifts will be postponed until the season of calving is over.

E4 - Lifts located in goshawk nesting area: response of goshawks is not positively determinable.

Unless lifts are moved, some effects are predicted, but the response of the birds to nearby construction and forest clearing is not known; therefore, even moving of the lifts may cause some effects.

A1 - Disruption, during flood-prevention use of channel, of artifacts possibly located along stream banks.

Use of the west primary channel of the creek may lead to disruption of artifacts suspected to be located along its banks. Some positive effects may occur because previously unknown deposits are uncovered, but negative effects are also possible resulting from the fact that these deposits may be lost or disturbed during floods.



ENVIRONMENTAL SUMMARY

PRIMARY STUDY AREA

RESULTANT DEVELOPMENT IMPACT

BY BEARDSLEY, DAVIS ASSOC. INC.

G1	POSSIBLE DOWNSLOPE MOVEMENT OF LIFT LINE G.
G2	POTENTIAL FOR SHORT-TERM FLOODING AT TIMES OF MAJOR LOCAL SEISMIC ACTIVITY
E1	DISTURBANCE TO ELK CAUSED BY LIFTS CONSTRUCTED ON AND ADJACENT TO ELK WINTER RANGE: MAY CAUSE ELK TO MOVE INTO LESS DESIRABLE RANGE-POSSIBLE EVENTUAL DECLINE IN ELK HERD SIZE FROM THE PRESENT HERD OF AT LEAST 20
E2	DISTURBANCE IN A LOW DENSITY (3-5) MOOSE WINTERING AREA: PROBABLE EVENTUAL DECLINE AND LOSS OF SEVERAL MOOSE
E3	LIFTS PLACED IN AN ELK CALVING AREA: ELK MAY NOT CALVE IN AREA
E4	LIFTS LOCATED IN A GOSHAWK NESTING AREA: GOSHAWK RESPONSE NOT POSITIVELY DETERMINABLE
A1	DISRUPTION, DURING FLOOD PREVENTION USE OF CHANNEL, OF ARTIFACTS POSSIBLY LOCATED ALONG STREAM BANKS

DEGREE OF IMPACT

- POTENTIAL SEVERE IMPACT
- POTENTIAL MODERATE IMPACT
- POTENTIAL LOW OR SHORT-TERM IMPACT

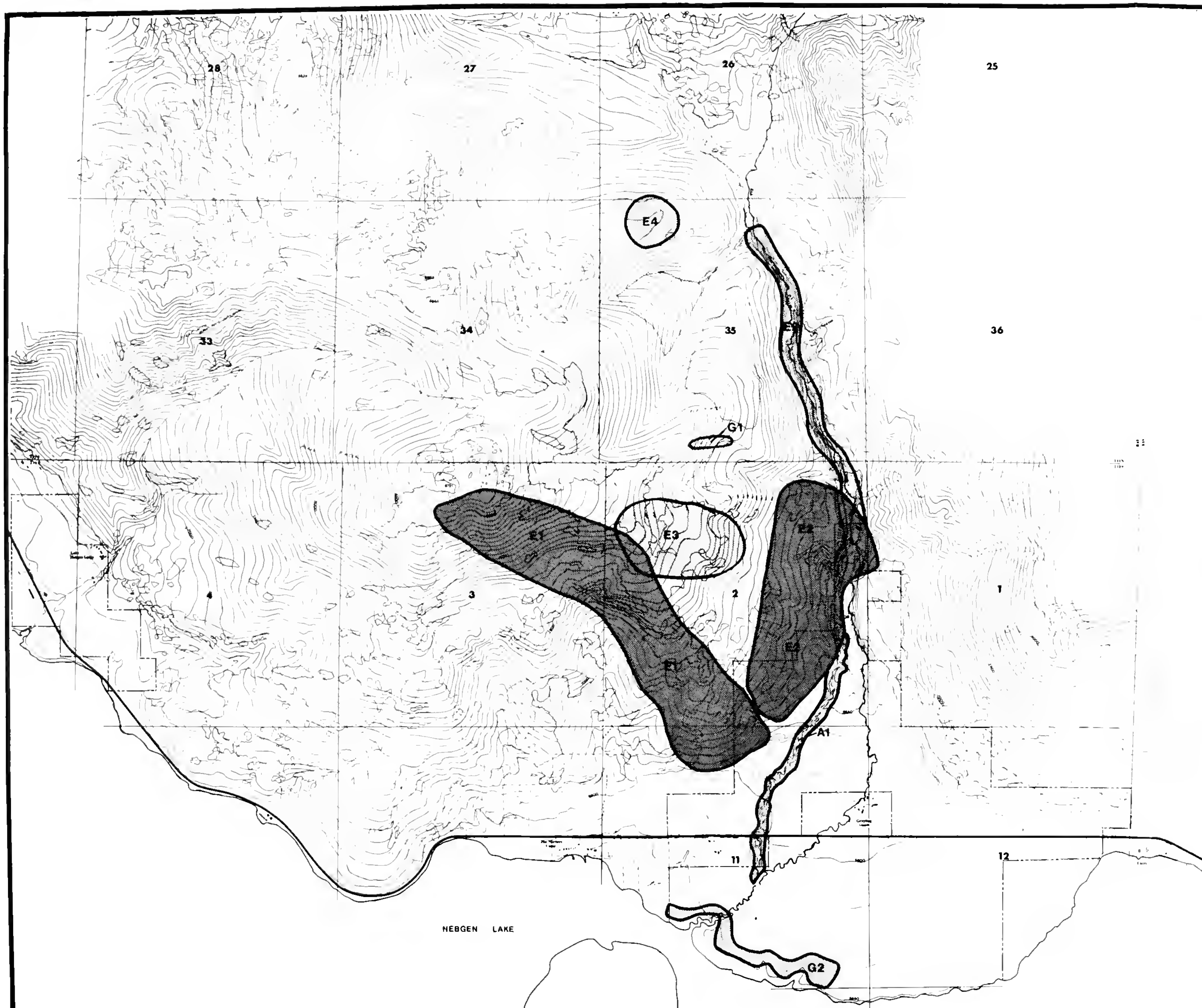
SKI YELLOWSTONE

SKI YELLOWSTONE INC.

WEST YELLOWSTONE, MONTANA

SCALE. 1" = 2000

OCTOBER 1973



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SCALE 1" 2000

OCTOBER 1973

III. Bio-Physical Components

III. Bio-Physical Components

PREFACE TO THE BIOPHYSICAL REPORT

John Montagne, Coordinator, Biophysical Team

Presented herewith are the results of studies accomplished at the request of and with the financial support of Ski Yellowstone during the months of June, July, and August, 1973. The Plant and Animal Ecology work was commenced slightly earlier. The team of consultants who authored the reports were recruited from among those with professed interest in applying their science to the benefit of mankind in the process of land use planning. The team was charged with the discovery of bio-physical attributes of the "on-site" and "off-site" area and were directed by the Corporation and the Planner not to sidestep problems seemingly incompatible with general development of the proposed recreation complex. The final result, then, is a report of unique thoroughness for a proposed development site, and one which is as academically broad as it is applied to the problems of development, pro and con. The Team not only turned up problems typical in the land use planning process of the day, but helped to suggest the mitigation of those problems so as to reduce or eliminate their impact on the environment. Not surprisingly, many bio-physical aspects of Red Canyon would be enhanced if the proposed development is carried out. It has been a distinct pleasure to work under this cooperative spirit, and we believe the product to be a true and objective model of the bio-physical situation.

The Bio-physical Report was written largely for the informed layman. In most cases, where unusual technicalities are involved, terms and concepts are explained well enough to be easily understood. In some phases, such as the Limnology, or the Water Quality reports, terms are necessarily technical and directed toward the use of engineers and technical experts whose duty it will be to apply the concepts to the design of structures and other technical mechanisms. Time limitations did not allow a complete year-long observation period, as would be ideally desired, but in those cases where yearly evidence was critical, use of past records reduced the conjectures considerably. Although it would have been more ideal to have compiled a truly interdisciplinary report demonstrating the interactions of one phase of the environment with the other, we have had to settle largely for a multidisciplinary result. We rely on the reader's ability to work back and forth from one report to another to gain the necessary interdisciplinary perspective. If time permits, we will attempt to utilize the "Environmental Land Unit" approach insofar as Climatology, Geology, Soils, Hydrology, Plant Ecology, and Animal Ecology are concerned. At least this interdisciplinary approach will be represented to the U.S. Forest Service as an unofficial report, and it has promise of usefulness in the ultimate inventory.

The bio-physical section is organized in nine separate articles. Identified with the authors and their credentials, these reports are:

1. Weather and Climate of the Red Canyon - Mt. Hebgen Area, Gallatin County, Mt.
   by Val. L. Mitchell, Ph.D., Associate Professor of Meteorology, Montana State University

2. Applied Geology at Red Canyon Area, Hebgen Lake, Gallatin County, Mt.
   by John Montagne, Ph.D., Certified Professional Geologist, Professor of Geology, Montana State University, and Robert H. Page, B.A., Geological Consultant

3. Soils and Surficial Geology Inventory of the Mount Hebgen-Red Canyon Area, with Interpretations for Development
   by Clifford Montagne, M.S., Research Assistant in Soils, Montana State University

4. An Evaluation of the Hydrological Characteristics of Red Canyon Creek, Gallatin County, Mt.
   by Donald Alford, Ph.D., Geophysical Consultant

5. The Limnology of the Grayling Arm of Hebgen Lake, Gallatin County, Mt.
   by John C. Wright, Ph.D., Professor of Botany, Montana State University

6. Survey of Surface and Ground Water Quality, Red Canyon and Northeast Hebgen Lake Area, Gallatin County, Mt.
   by J. J. Jezeski, Ph.D., Professor of Microbiology, Montana State University, and Gary Bissonette, M.S., Research Associate in Microbiology, Montana State University

7. Plant Ecology of the Red Canyon Area, Hebgen Lake, Gallatin County, Mt.
   by Brent M. Haglund, M.S., Instructor in Biology, Augustana College, S.D.

8. Wildlife Report at Red Canyon Area, Hebgen Lake, Gallatin County, Mt.
   by Brent M. Haglund, M.S., Instructor in Biology, Augustana College, S.D.

9. An Inventory and Impact Evaluation of Archaeological and Historic Resources Located on and Adjacent to Properties Near Hebgen Lake to be Developed by Ski Yellowstone, Inc., A Summary Report
   by Leslie B. Davis, Ph.D., Associate Professor of Anthropology, Montana State University
   Adjunct architectural report by J. N. DeHaas, Jr., M. Ed. Certified Architect, Professor of Architecture, Montana State University

Summarizing the entire Bio-physical Report, there appear to be relatively few serious limitations to development, and what limitations do exist can be minimized in most cases. Let us admit that any man-made construction or modification involves change and impact in any natural area. The question of values gained vs. values lost is always a difficult and subjective consideration and it is likely that as many people consider a well conceived recreation area an asset to the landscape as do those who think of it as an intrusion. Under the values lost category, there may simply be some unrecoverable aspects which could be listed as "trade-offs" in vernacular of the day. In the case of remote possibility of renewed fault movement in a zone on Red Canyon Fan, a prime building site, the hazard has been avoided by staying clear of the fault zone. The development, likewise, would by its own attributes remain clear of rockfall areas. Some sensitivities remain insofar as winter habitat for moose is concerned, but adjustment can be made to help mitigate any problem with respect to calving elk.

The monitoring of archaeological sites will help reduce any objectionable effect there. These have been the really difficult problems to deal with. While

it would be unfair to the reader to predetermine what his opinion may be, from the coordinator's point of view the impact of the development on bio-physical aspects, and the impact of the bio-physical aspects on the development, appear to be tolerable and workable.

WEATHER AND CLIMATE

Val L. Mitchell

INTRODUCTION

The weather and climate of the Red Canyon area contribute significantly to make the area desirable as a year round recreation area. Summers are usually very pleasant for outdoor recreation with warm days and cool nights and little precipitation. The area is cold in winter, but not as cold as the reputation of the area might have it. Winter temperatures are cold enough that the substantial snowfall remains on the ground throughout the winter, giving the area considerable potential for snowbased outdoor recreation.

The following report is an effort to describe the weather and climate of the Mt. Hebgen-Red Canyon area in a way that is useful for the planning and development of a major year round recreation complex. Weather data in the Red Canyon area are very limited, hence the data that follows are estimates for the area of interest based on a knowledge of mountain meteorology and the weather records of West Yellowstone, Hebgen Dam, and to a much lesser degree, Horse Butte lookout. Appreciation is expressed to the many people who have taken weather observations at these locations over the years.

TEMPERATURE

The only temperature records available in Red Canyon are those taken from a thermograph network set up on the east slope of Mt. Hebgen in late January, 1973. However, a good long term temperature record is available for Hebgen Dam, 8 miles west-northwest of the mouth of Red Canyon. The Hebgen Dam record provides the basis of the following discussion of temperature in the Red Canyon-Mt. Hebgen area. The thermograph network data have been used for guidance whenever they were helpful.

As stated previously summers in the Red Canyon area are mild and winters are cold. This is borne out by the estimates of mean monthly maximum, minimum and mean temperatures for the proposed village site at the mouth of Red Canyon presented in Table 1.

January is the coldest month with a mean maximum temperature of 22 F and a mean minimum temperature of 5 F. Although the West Yellowstone-Hebgen Lake has the reputation of being very cold in winter, these figures suggest that there are periods even during January that are pleasant and mild for winter.

The mean maximum for July is 78 F and the mean minimum is 46 F. Summer days tend to be very pleasant but the nights are usually distinctly cool. There are some days during the summer when the diurnal range (the difference between the maximum temperature and the minimum temperature) is about 50 degrees. This large temperature change from day to night should be considered when planning evening or nighttime outdoor recreation activities.

Typical of most places in the middle latitudes, the Red Canyon area experiences temperature fluctuations resulting from the movement of fronts and pressure systems through the area. Tables 2 and 3 have been prepared in an effort to show both the variability of temperature and the proportion of time extreme temperatures occur. Table 2 presents the percent of days of each month that the maximum temperatures can be expected to be lower than the selected values indicated. For example, the maximum temperature on 86% of the days in January will probably be 32 F or colder, while maximum temperatures are below 0 F on 6% of the days in January.

Table 2 shows that, while it does get cold in the Red Canyon area, the percentage of the time that it is very cold is small. Maximum temperatures below 0 F can be expected only 6% of the time in January, 1% of the time in February, and 4% of the time in December. On the other hand, maximum temperatures above 32 F can be expected 14% of the time. (The percent of days that maximum or minimum temperatures are above a certain level can be obtained from Tables 2 and 3 by subtracting the percent figure in the body of the table from 100.)

Maximum temperatures in summer rarely exceed 90 F, but cool days when the maximum does not exceed 70 F are not uncommon, especially in August.

Winter minimum temperatures (Table 3) can be very cold, with the temperature occasionally reaching -40 F. However, the percent of days when these very cold temperatures occur is small. During December, January, and February, minimum temperatures below zero can be expected about one third of the time. This will usually not be a problem for outdoor recreation since maximum temperatures on these days will usually be at least 10 F. Also, temperature inversions are quite likely when the minimum temperatures at the village site are below zero, with the result that it will usually be warmer in the morning on the slopes of Mt. Hebgen than at the village.

As suggested before, summer minimum temperatures can be quite cool. For example, in July and August the minimum temperatures on about one half of the days can be expected to be 45 F or colder.

It should be noted that Tables 2 and 3 are based on a number of years and that the percent frequency of temperature for any one month may depart from the estimates in the tables.

The duration of very cold weather is often as important as the temperature itself. While it does get very cold in the Red Canyon area from time to time, the cold periods are usually of short (1-3 days) duration. In the 36 year period from January 1938 to February 1973, maximum temperatures at Hebgen Dam remained at or below 0 F for 4 or more days on only 5 occasions. The longest period of cold weather was in December, 1972 when the maximum temperature remained at or below zero for 8 days. This was the result of an unusually large and severe arctic outbreak that covered most of the western United States.

The temperature estimates just given are for the proposed village area at the mouth of Red Canyon. These estimates cannot be realistically applied to Mt. Hebgen. Although temperature information would be desirable, especially for the top of Mt. Hebgen, such information is not available and reasonable

estimates cannot be made with currently existing data. The best that can be done at the present time is to present, in a very broad manner, some general relationships between a mountain ridge or peak and the adjacent valley floor using the short term thermograph records from Mt. Hebgen and the weather records from the Horse Butte lookout, which are for summers only, as guidance.

The temperatures on top of Mt. Hebgen should be more moderate than those at the mouth of Red Canyon. Daytime temperatures should be from 3 to 10 degrees cooler than the valley and nighttime temperatures should vary between a few degrees cooler to perhaps as much as 30 degrees warmer than the valley floor. The large positive difference at night results from the formation of temperature inversions which form frequently at night. During the winter, the top of Mt. Hebgen should be considerably warmer than the valley floor during periods of intensely cold weather. Temperatures on the top of Mt. Hebgen probably rarely drop much below 0 F.

Another situation when Mt. Hebgen will usually be warmer than the valley below is on clear summer nights, when cooling by radiation is usually at a maximum. The temperature difference here, however, will not be as great as that during the very cold periods of winter and is not of the practical significance of the wintertime situation. More will be said about temperature inversions in the discussion of air pollution.

PRECIPITATION

The best estimate of the monthly and annual precipitation at the proposed village site at the mouth of Red Canyon is the precipitation data from Hebgen Dam. Although the precipitation at the Dam is not representative of the precipitation on the ski areas of Mt. Hebgen, it is probably quite representative of the village site. Hence, the following estimates for the village site are based on the Hebgen Dam precipitation records.

The mean precipitation for each month is presented in Table 4. The average annual precipitation for the 1931-1970 period is 27.41 inches. There are two rather distinct wet seasons, winter and late spring. The wettest month is June, with an average of 3.11 inches but January precipitation is nearly as high with an average of 3.05 inches. Of the total precipitation, 48.9% falls during the winter (November through March) and 20.6% falls during May and June. The driest season of the year runs from July through September.

An important characteristic of the precipitation in the Hebgen Lake area is variability. In addition to mean precipitation, Table 4 also presents the standard deviation of precipitation, greatest amount, and least amount for each month for the 40 year period considered. As can be seen, any month of the year can be very wet or very dry. Nine of the twelve months of the year have received more than five inches of precipitation, with the greatest total going over seven inches in June and December. On the other hand, each month has had at least one occurrence of precipitation less than one inch, with the least precipitation in August, October, and November being less than 0.1 inches.

The driest year during the period considered was 1931 when only 19.44 inches of precipitation fell. The wettest year was 1964 with just over 38 inches of precipitation. It should be noted that the decade from 1961 to 1970 was considerably wetter than the preceding thirty years. Each year in this decade was wetter than the average for the preceding thirty years. During three years, 1964, 1967, and 1970, over 35 inches of precipitation fell. Both 1971 and 1972 were also above the long term average. There is no way of determining whether or not this trend of increased precipitation will continue.

From a recreation viewpoint, one pertinent factor relating to precipitation is the number of days in a given month when precipitation occurs. For skiing, frequent precipitation has distinct benefits as well as a few disadvantages. However, from the viewpoint of summer outdoor recreation, frequent rainy weather is a distinct disadvantage. Estimates of the average number of days with measurable (.01 inches or more) precipitation to be expected are given in Table 5 for each month. These estimates may be slightly high since they are based on the period from 1960 through 1972, a period of above average precipitation, but they are sufficiently accurate to serve as guidelines. During the winter and late spring, precipitation can be expected on nearly half of the days. Summer and fall are clearly the best months from a low precipitation standpoint, but no month can be thought of as precipitation free.

The hydrologic aspects of precipitation are treated in the hydrology section of this report.

CLOUD COVER

Estimates of cloud cover for the Red Canyon area are given in Table 6. These estimates are based on weather observations taken by the U. S. Weather Service in West Yellowstone at three hour intervals. Presented are the percent of daylight hours in each month that are clear, partly cloudy (from 1/10 to and including 5/10 of the sky covered with clouds), mostly cloudy (from 6/10 to and including 9/10 of the sky covered with clouds), and overcast. Also presented are the mean cloud cover from sunrise to sunset for each month and an estimate of the percent possible sunshine received during each month. The estimates of cloud cover do not differentiate between low heavy clouds and high thin (cirrus) clouds that rarely hide the sun, hence there are some days included in the mostly cloudy or overcast categories that are somewhat sunny even though high thin clouds are present.

The data in Table 6 show that overcast conditions are very common in winter. If the clear and partly cloudy days are considered to be nice days and the mostly cloudy and overcast days are considered as cloudy days, it is cloudy almost 70% of the time in January. In July, clear or partly cloudy weather conditions prevail about 75% of the time.

From the standpoint of outdoor recreation, the month of June requires special comment. June is usually considered to be the first month of summer and the beginning of the vacation season. However, in the Red Canyon area, June is really a spring month rather than the first month of summer. It is the month of maximum average precipitation and the skies are cloudy about 50% of the time.

Outdoor recreation can be hampered considerably by the weather during this month. This is probably the only month of the year when the weather in the Red Canyon area is just the opposite of what is desired from an outdoor recreation viewpoint.

In contrast, July, August, and September tend to be sunny and dry.

WIND

The winds in the Red Canyon area, as in most mountainous terrain, are strongly controlled by the local topography. Except for those periods when a strong pressure system, usually a low or a front in the area, overrides the local influence, a typical mountain-valley wind system prevails in Red Canyon and on the alluvial fan at the mouth of the canyon. This makes the winds in the area very predictable much of the time.

At night, the airflow at the surface is down the canyon at from five to ten miles per hour. As the canyon mouth broadens, the airflow pattern fans out in the manner shown in Figure 1. During the daytime, the airflow is up the canyon basically as shown in Figure 2. Although daytime airflow across the alluvial fan is basically as shown in Figure 2, measurements at Grayling show that at any time it may vary from southeast to southwest. This upcanyon movement is usually reinforced by the southwest winds that prevail during daylight hours in the entire West Yellowstone basin, resulting in upcanyon wind speeds of five to ten miles per hour, which is stronger than typical upcanyon airflow. This typical diurnal airflow pattern prevails most of the time during the summer, and much of the time in the other seasons. It is best developed during good weather.

The prevailing wind at the village site is from the south or southwest. However, in terms of the total number of hours of wind from a given direction, a downcanyon wind (north wind) is almost as common as a south or southwest wind because of the strong topographic control of the nighttime winds.

The diurnal airflow pattern should not present any problems, except possibly in the siting of the sewage disposal facilities. It would be desirable to locate the waste water treatment facilities such that there is a minimum of air movement from the treatment plant toward the village. A site east of the abandoned town of Grayling, as suggested in Conceptual Land Use Plan IIIc, is the best site north of Highway 287. This site does have the disadvantage that a southeast wind will carry odors from the treatment facility toward the village site. Although south and southwest winds are more common during the day than southeast winds, southeast winds do occur. During a three week period in June and early July, southeast winds occurred at Grayling about 6% of the time.

From strictly a wind viewpoint, a site as far southeast of Grayling as possible would be the preferred location for the waste water treatment facilities. However, wind direction is just one of several factors that must be considered in locating this plant.

Less information is available concerning the winds during storm periods than during nonstorm periods. The deflection of wind by mountains is such that strong winds other than up or down canyon will be rare in the bottom of Red Canyon. At the village site, the wind direction will be less controlled by topography. As cold fronts approach the area, the village site will be subjected to fairly strong, gusty south to southwest winds. After a cold front passes through the area, the winds will be westerly but remain strong and gusty. In either situation, sustained wind speeds greater than 25 miles per hour will be rare. However, gusts to 40 or 50 miles per hour could occur. Usually winds associated with a cold front will not be this strong.

The strongest winds in the area will probably occur during thunderstorms. It is not uncommon for peak gusts in thunderstorms to exceed 50 miles per hour.

There is nothing to suggest that the proposed village site is subject to winds that are stronger than those found in most locations. As long as all facilities are properly constructed, wind at the village site and in the bottom of Red Canyon should not present problems.

Thus far, this discussion of wind has not dealt with the important problem of wind on Mt. Hebgen. Unfortunately, the winds on Mt. Hebgen present a much more complex problem than the winds on the valley floor. About the only statement that can be made with confidence about wind speed and direction on a mountain is that each mountain or ridge must be considered by itself. Hence, little information concerning the winds on Mt. Hebgen can be obtained from any source except measurements on Mt. Hebgen itself.

The prevailing wind direction on top of Mt. Hebgen is probably southwest. There is no way of predicting wind speeds on Mt. Hebgen. It is encouraging that little evidence of wind scour or drifting has been found by those who spent time on the mountain last winter.

It is strongly recommended that wind speed and direction measurements be taken on Mt. Hebgen during the coming winter. Discussions with Hans Geier indicate that this is planned. It should be stressed, however, that obtaining usable measurements of wind speed and direction on a mountain during winter is very difficult. Since commercial power is not available on the mountain, the measuring equipment and recorders will have to be battery powered. It may be necessary to bury the batteries to protect them from the cold. This means that the wind measuring instruments should be set up and thoroughly checked out before snow begins to accumulate on the mountain. It will also be necessary to check the instruments frequently, probably every few days, to ensure that they are working properly.

The measurement of wind speed and direction on Mt. Hebgen during winter is very important and yet will be very difficult. It is strongly suggested that a person with experience in this type of measuring problem be involved in the purchase and set up of this equipment.

EVAPOTRANSPIRATION

In order to properly design the waste water treatment facilities, it is important to know as accurately as possible what the monthly and annual rates of evaporation can be expected at the mouth of Red Canyon. Unfortunately, there is no good method to calculate evaporation (or evapotranspiration if plants are involved) and the time and financial limitations of this study have not permitted the measurement of evaporation in the area.

In order to have some estimate of evaporation in the Red Canyon area the potential evapotranspiration (the maximum amount of evapotranspiration possible when water is readily available) was calculated for the area of interest using a method developed by Thornthwaite*. The monthly values obtained are given in Table 7. Thornthwaite assumes that there is no evapotranspiration during a month when the mean temperature is below 32 F. The estimated annual evapotranspiration by this method is 19 inches.

There are several energy budget methods of estimating evapotranspiration, but the meteorological data needed to use them are not available in the Hebgen Lake area. A study done in Australia* compared measured evapotranspiration values with those obtained by several methods of calculating the evapotranspiration. The results suggest that the Thornthwaite method underestimates the actual evapotranspiration. Using these results for a crude correction factor on the Red Canyon potential evapotranspiration figure suggests that actual evapotranspiration from an open water surface is probably near 30 inches per year. The monthly corrected values are given in Table 7.

IMPACT ON ATMOSPHERIC ENVIRONMENT

In all probability, the only way that the development of a year round recreation complex in and around Red Canyon can adversely affect the atmospheric environment is through air pollution. Since very stable atmospheric conditions, which tend to trap air pollutants and retain them in the area, are very common in the West Yellowstone-Hebgen Lake Basin, air pollution is definitely a potential problem.

The quality of the air in the Red Canyon is presently good. However, temperature inversions and other stable conditions develop in the area during most nights and during very cold weather. Usually, the atmosphere becomes sufficiently unstable during the day to permit pollutants trapped in the basin to be flushed out. An exception to this is during very cold periods when temperature inversions persist throughout the day.

The point of prime concern in air pollution in the Red Canyon area is not as much the violation of state and federal air pollution standards as it is the preservation of the generally good visibility that is usually present. The scenery in the Red Canyon area is one of its selling points, and any obscuration of that scenery behind a pall of smoke is undesirable.

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* see references at end of report

The key to preventing air pollution in the area of concern lies in the limitation of air pollution sources. It is apparently planned to use electricity to heat all facilities since natural gas is not available in the area. It is important that this be the case.

As long as a clean source of heat is used, the only apparent sources of air pollution are fireplaces and automobiles. Automobiles should not present much of a problem since their use will not be concentrated in one area. Fireplaces, however, present a different problem. A fireplace is a desirable feature in living units, but in a village as large as the one being proposed, if every living unit has a fireplace there will be times when the accumulation of air pollutants in the area will be very noticeable. The writer is not aware of any method usable within the limitations of this study to specify the maximum number of fireplaces that could be permitted before problems develop. Therefore an arbitrary limit on the number of fireplaces will have to be set, using as a guideline the fact that as the number of fireplaces increases, the problem increases. Even though caution should be exercised, a total ban on fireplaces is probably not called for.

During the construction phase of the proposed project an increase in dust will probably occur, but once construction is complete, dust should not be a problem.

With respect to the impact of the project on the atmosphere in ways other than through air pollution, all such impacts are expected to be minimal and local. The clearing of areas on Mt. Hebgen for ski trails will affect the microclimate of the cleared area and may result in a change of plant species. But unless new species are deliberately introduced, the plants that move into the cleared areas will be those that are already found in the nonforested areas of the mountain.

Similarly, a change in microclimate will occur on the alluvial fan where the village is constructed. But the area affected will be limited to the immediate village area. The overall impact on the atmosphere of such actions as the clearing of ski trails or the construction of a village the size of the one planned is so small that it is of no concern.

CONCLUSIONS AND RECOMMENDATIONS

The weather and climate of the Mt. Hebgen-Red Canyon area are well suited for the year round recreation development proposed. There are only two ways in which the weather will provide an unusual limitation to outdoor recreation. There will be periods when it is too cold for most people to ski. These are usually of short duration and should not present a problem. Also, the weather in June is often not as conducive to outdoor activities as might be expected by persons not familiar with the climate of the area.

As far as the impact of the development on the atmospheric environment is concerned, air pollution is the only potential problem. For this reason, it is recommended that the number of air pollution sources, such as fireplaces, be restricted. The atmospheric environment of the area is of high quality at the present time and should remain so as long as air pollution sources are carefully controlled.

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FIGURE 1 and 2

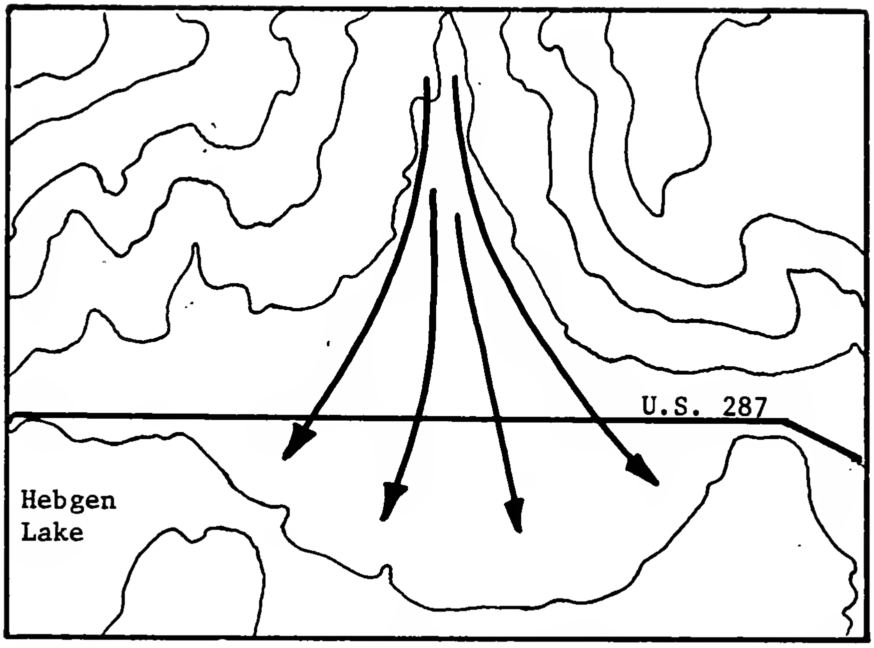

Figure 1 Generalized typical nighttime airflow from Red Canyon.

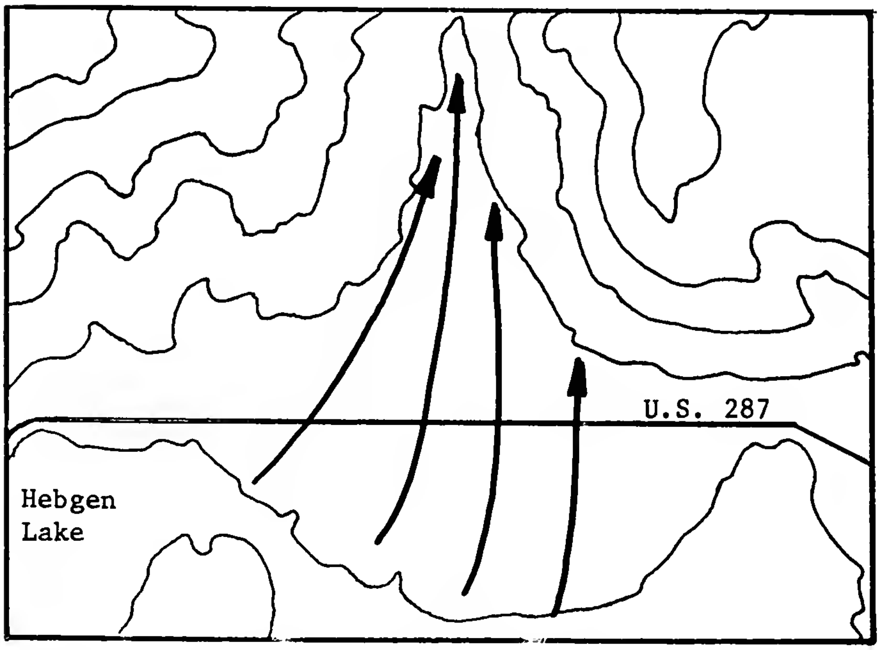

Figure 2 Generalized typical daytime airflow into Red Canyon.

TABLE 1

Table 1 Temperature Data Estimates for Red Canyon Village Site (in F)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Max	22	28	36	47	59	68	78	77	66	52	35	24	
Min	5	6	13	25	34	40	46	44	37	27	19	8	
Mean	13.5	17.0	24.5	36.0	46.5	54.0	62.0	60.5	51.5	39.5	27.0	16.0	37.3

TABLE 2

Table 2 Percent of days with maximum temperature at or below selected values.

Temp °F	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Temp °F
-25	*												-25
-20	1												-20
-15	1											*	-15
-10	2											*	-10
-5	3											2	-5
0	6	1										4	0
5	10	2	*									7	5
10	16	3	1								*	12	10
15	27	8	3								*	24	15
20	44	18	6							1	4	40	20
25	60	36	12	1						1	15	60	25
30	78	60	28	2	*				*	3	32	80	30
32	86	69	36	3	*				*	5	42	88	32
35	95	83	52	9	*				1	9	58	96	35
40	99	96	73	31	3				2	18	79	99	40
45		99	85	55	10	1			6	29	92		45
50			94	77	22	6		1	12	43	97		50
55			99	90	36	14		3	19	60	99		55
60				97	54	26	1	6	30	79			60
65				99	72	41	2	9	46	90			65
70					86	59	8	17	64	97			70
75					96	76	24	33	83	99			75
80					99	92	57	57	96				80
85						99	89	89	99				85
90							99	99					90

* less than 1% but greater than 0%

<u>TABLE 3</u>

Table 3 Percent of days with minimum temperature at or below selected values.

Temp °F	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Temp °F
-40	1												-40
-35	2	*										*	-35
-30	3	1	*									*	-30
-25	6	2	1									2	-25
-20	10	4	4									5	-20
-15	13	8	6									10	-15
-10	19	14	12									15	-10
-5	25	22	17	1							*	21	-5
0	34	30	22	1							2	32	0
5	45	39	28	2						1	5	42	5
10	57	49	38	6						2	12	55	10
15	67	63	53	16	1					4	26	67	15
20	78	76	68	29	3				1	9	41	79	20
25	86	87	81	51	9				3	21	61	89	25
30	95	94	91	76	26	2		1	13	49	84	96	30
32	98	96	95	85	38	5	*	1	20	61	91	99	32
35	99	99	99	96	60	13	2	4	35	80	98		35
40				99	90	40	11	15	62	95			40
45					99	80	43	54	86	99			45
50						98	83	84	97				50
55						99	97	96	99				55
60							99	99					60

* less than 1% but greater than 0%

TABLE 4

Table 4 Precipitation Data Estimates for Red Canyon Area (in inches)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean	3.05	2.47	2.40	1.81	2.53	3.11	1.54	1.47	1.65	1.84	2.54	2.94	27.41
Std. Dev.	1.44	1.06	1.22	.97	1.26	1.54	.89	1.28	1.22	1.28	1.16	1.31	5.06
Greatest	6.90	5.33	5.06	4.50	6.02	7.50	3.86	6.28	5.42	6.22	4.80	7.10	38.06
Least	.66	.66	.52	.31	.16	.67	.30	.06	.13	0	.08	.90	19.44

TABLE 5

Table 5 Estimated Average Number of days with measurable Precipitation

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
17	12	11	9	11	13	7	7	8	7	12	15	129

TABLE 6

Table 6 Sunrise to Sunset Cloud Cover Estimates for Red Canyon Area

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Clear	15*	19	23	21	32	21	46	46	38	29	26	22
Partly Cloudy	15	17	19	17	24	28	32	28	25	22	17	15
Mostly Cloudy	14	17	17	20	16	24	13	13	18	20	11	10
Overcast	56	47	41	42	28	27	9	13	19	29	45	53
Mean Cloud Cover **	7.2	6.6	6.1	6.3	4.9	5.6	3.0	3.3	4.1	5.2	6.0	6.6
% Possible Sunshine	52	59	64	62	73	68	83	82	77	71	64	59

* average percent of daylight hours cloud condition prevails.

** in tenths of the sky covered with clouds.

TABLE 7

Table 7 Evapotranspiration Estimates (in inches)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Thornthwaite	0	0	0	0.7	2.3	3.5	4.8	4.0	2.5	1.2	0	0	19.0
Corrected	0	0	0	1.1	3.7	5.6	7.7	6.4	4.0	1.9	0	0	30.4

APPLIED GEOLOGY

John Montagne and Robert H. Page

INTRODUCTION

In this report the authors have developed geologic interpretations for selected sites and applied the concepts to the problems of engineering and development for the proposed Ski Yellowstone Resort Complex. Parts of the months of June and July, 1973 were spent in the field, and for the most part the detailed work is limited to the west canyon wall of Red Canyon Creek, including the summit of Mt. Hebgen and the ridge extending from that landmark northward to Kirkwood Ridge. The thrust of the report is directed toward a readership of "middle of the road" layman scientist, and some technical geologic terms will be defined if they are otherwise unavoidable in description.

Red Canyon is located approximately 10 miles north of West Yellowstone and five miles west of the Duck Creek "Y" on Highway 287, north of Grayling Arm of Hebgen Lake. Elevations range from approximately 6500 feet above sea level on the valley bottoms to 8700 feet on the summit of Mt. Hebgen. Climate is such that moderately heavy winter snows and spring rains contrast markedly to semi-arid summer conditions except at the higher elevations. The total yearly rainfall equivalent at West Yellowstone is only 20 inches.

PREVIOUS INVESTIGATIONS

Because of the attention focused on this area by the spectacular structural displacements of August 17, 1959, and the associated landslide and earthquake phenomena, considerable scientific information has been published about the area since that period. Prior to that time, the area was in the backwash of Yellowstone Park exploration, but never received much attention except in reconnaissance mapping by D. D. Condit and E. H. Finch, 1916, and on the State Map of Montana compiled by C. P. Ross, D. A. Andrews, and I. J. Witkind in 1955.

The leading paper describing comprehensive aspects of the 1959 Earthquake is U. S. Geological Survey Professional Paper 435 (1964) to which many authors contributed, following the lead of I. J. Witkind who was mapping on the north shore of Hebgen Lake at the time of the earthquake. To them, and in particular to the work of Witkind, we are greatly indebted, for this groundwork provided immediate details which helped focus attention on critical terrain without tedious initial reconnaissance. We have drawn freely upon this work both in the compilation of Figure 1, and in the course of text preparation. At least one important function of the present paper is to bring forth the salient aspects of previous work so that the developer can be apprised of such geologic information as may be critical to proper engineering activities in the Red Canyon area. We have contributed further data as the result of field work during the summer of 1973.

Woodward-Clevenger and Associates (1973) prepared an engineering geology report for Ski Yellowstone, Inc., covering geologic aspects and risks from a construction standpoint in the Red Canyon area. This report has been useful in focusing attention on problems and served as another geologic voice where decisions and recommendations concerning public safety are difficult, necessarily indefinite, and critical.

GEOMORPHOLOGY

Geomorphology, loosely defined, means "the shape of the earth". Commonly the topic is covered as a detail in the geologic description of surface features in given areas. Since the geomorphology of any area is importantly related to reactions of erosional and depositional agents upon underlying rock material, geomorphology is often a "tip-off" to the gross aspects of general geology. Likewise, the geomorphic expression reflects salient aspects of geologic history; in particular relatively recent geologic history. We can make good use of geomorphology in the Red Canyon area for the above reasons.

GLACIATION

By analyzing curvilinear and irregular topography on the floor of the Hebgen Lake Basin and comparing it to similar topography elsewhere in the Rocky Mountains, we can predict that Horse Butte and its associated hooked peninsula, that forms the south side of "The Narrows" in Grayling Arm of Hebgen Lake, was the dumping ground for a sizeable ice sheet emanating from Yellowstone Park. The lateral debris from this glacier was spilled out along what are now highway cuts, from the Red Canyon fan eastward across Grayling Creek to the high point in Highway 191 a mile north of the Duck Creek "Y". For reasons not detailed here, this glaciation is called the Bull Lake Glaciation. The ancestral Red Canyon Creek must have smoothed off remnants of this moraine where the Red Canyon fan is now developed, for there is no sign of moraine on the fan. A second and younger glacial sequence also occupied valley floors in areas near Red Canyon, and its Yellowstone piedmont lobe terminated east of the west border of Yellowstone. This was the Pinedale glaciation, which waned about ten thousand years ago.

Pre-Bull Lake glaciation occurred in the Hebgen Basin as indicated by scattered erratics strewn between Horse Butte and Hebgen Dame. Anomalous angular Precambrian boulders up to five feet in maximum diameters are scattered along the west side of Red Canyon Creek near the place where the creek crosses the Red Canyon fault, and these are thought to be pre-Bull Lake, likewise. Richmond (1964) has summarized these points.

If Pinedale and Bull Lake ice did not occupy the lower Red Canyon area, phenomena associated with the glacial climate did. Bull Lake age alluvial fans and mudflows project high into the canyon sides, and Pinedale activity caused their dissection and the formation of inner fans projecting to the present drainage levels.

We can conclude that the direct effect of glaciation is not very important within Red Canyon proper, that great piedmont ice lobes occupied the plain at the canyon mouth, and that modern topographic expression existed at least as early as Pinedale time and basically as early as Bull Lake time, which was approximately 130,000 years before the Present. Geomorphic features of Bull Lake and Pinedale age occur in Red Canyon and were coincident in time with the ice advances of those ages.

STREAMS

Three important creeks flow into the Madison drainage in the Red Canyon vicinity. They are Red Canyon Creek, Grayling Creek, and Duck Creek. The degrees to which these drainage channels were downcut during the latter part of Pleistocene time (i.e. $\pm$ 300,000 years) depends to an extent upon the structural setting from which erosion could take place. Whereas Duck Creek flows off a wide gently sloping alluvial plane already graded to the master drainage, and could not therefore muster the energy to downcut into a steep-sided deep canyon, Grayling and Red Canyon creeks have both sharply dissected their canyons to deep "V" shaped forms in places, thus hinting at the youthful nature of these streams in their latter day history.

Red Canyon has a dry fork emanating from a large dry valley south of Kirkwood Ridge. Although hydrographic information by Dr. Donald Alford in another section of this report will examine this anomaly in some detail, it is nevertheless fitting to mention here that one explanation for the lack of surface water is the great abundance of limestone exposed on the surface. Water has a tendency to flow into and dissolve along joints in limestone, especially Mississippian age limestone, and thus to disappear from the surface in a system of solution formed caverns. While caverns are unknown in the area, they probably do exist below the surface, and the Madison Limestone Group is notoriously prone to water absorption under these conditions. Fresh sink holes in the Madison Limestone on top of Mt. Hebgen attest to this activity and are a mild hazard to construction activities where they infrequently occur. Solution furrows and valleys on the ridge extend north from the summit of Mt. Hebgen, likewise, which show evidence of having been dissolved by ground water flow, later to be filled with wind-blown and residual silts and clays.

TERRACES

Terraces in the Red Canyon area are of two types--those that consist of debris deposited by streams that later dissected their flood plains, and those "structural terraces" on the canyon walls which represent the loci of rocks resistant enough to make cliff-like steps in the canyon wall topography.

True stream terraces are not conspicuous landforms in general, although they are important as ancient cultural sites along the streams. Most prominent among them are those terraces from 20 to 30 feet above present drainage on the west side of Red Canyon Creek along the edge of the lower alluvial fan. Rounded boulders covered by or contained in reddish sandy loam occur on the surface of this terrace system, and the valley wall side of the terraces are transitional with alluvial deposits from the upper slopes and chutes. Other

terraces or terrace remnants are present upstream, most with clear Pinedale or Bull Lake affinity. Of particular note is the Bull Lake Terrace along the dry (west) fork of Red Canyon Creek. This projects over 150 feet above the present drainage and forms the lower reach of a dangerous snow avalanche runout zone. Generally the terrace remnant appears to be depositional, but near the fork of the creek its top corresponds at least fortuitously with that of a rhyolite flow and with that of a Mississippian breccia.

The second type of terrace mentioned above are structural in origin and provide important clues to the underlying rock types, imparting a "layer cake" appearance to the topography in this area. They make the topography more interesting from a recreation viewpoint and can be utilized in various building and constructional activities if treated with proper caution and building technique. The cliffy parts correspond with major limestone units such as the Meagher, Pilgrim, Jefferson, or Madison, whereas the "treads" correspond with the less resistant shale units such as the Wolsey, Park, or Three Forks. The approximate contacts between these formations represented on Figure 1 were located mostly on the basis of the geomorphic expression of these units, for rarely is a clean-cut outcrop to be seen in this locality.

LANDSLIDES

Landslides and mass movements are of particular geomorphic interest in this area since they are sensitive to any physical changes that occur and therefore must receive special attention if construction is to be placed near or within them. Under the section on Soils and Surficial Geology, Clifford Montagne will treat the more technical aspects of slope stability. However, from the bedrock standpoint, slides show certain affinities and so they are mapped on Figure 1, and as part of the hazard limitations on Figure 2. Only four important presently active slides have been mapped. Undoubtedly many smaller and unimportant slides do exist. The four in question are all associated with the occurrence of the Cambrian Park Shale Formation in the presence of ground water. It is well known that clay shale such as the Park will not pass water through it, and also that the material becomes plastic and subject to flowage if saturated. Such is the case on all four earthflows mapped. The landslide or earthflow along the west half of the border between Sections 35 and 2 is the most important and prominent of slides and occurs amidst planned ski trails and lifts. The slide has retrogressed through the Park Shale and up into the Three Forks Shale, although the active part is apparently now restricted to the canyon bottom, but the shale is prominent along the stream course although out of place.

Another prominent slide, fortunately outside the zone of planned development, is at the east portal of Red Canyon directly below the multiple recent scarps of the Red Canyon Fault. This composite earthflow again involves the Park Shale and was triggered by the Hebgen Earthquake of 1959. It thus appears to be more or less directly related to the fault itself.

Slides with large debris piles that probably occurred during the closing stages of the glacial episode are located along the east wall of Red Canyon near the mouths of Coal Creek and an adjacent unnamed drainage. These slides are

clearly dissected or truncated by Red Canyon Creek today, but the accumulation zone is still impressive and contains large erratics of rhyolite lava, Cretaceous age sandstone and conglomerate blocks, as well as those of earlier geologic age. The rhyolite is of interest and importance since it can be clearly traced up Coal Creek to the top of the Red Canyon wall where a rhyolite flow extended into the Coal Creek drainage and provided extensive debris for the slide. Unstable lavas and sedimentary rocks here pose a continuing threat to Coal Creek Canyon even today. Although Richmond (1964) originally mapped the slide masses on the floor of Red Canyon at this locality as Bull Lake glacial moraine, (probably on the basis of the rhyolite erratics), we believe the deposit is clearly the result of a mudflow or earthflow from the top of the local canyon walls, since the rhyolite is sharply restricted to the Coal Creek drainage and does not occur as a boulder train emanating from the nearest upstream flow, at the fork of Red Canyon.

SOLUTION PHENOMENA

The abundance of Paleozoic limestone in the Red Canyon area makes it easy prey to solution activity. If there were no other indication of this, the lack of surface water throughout the area, and in particular in the dry fork of Red Canyon Creek would be sufficient evidence. Intuitively, it appears as though the Madison Limestone Group which occupies the higher elevations of Mt. Hebgen and other ridge lines is more susceptible than other carbonates to modification by solution. The dissolved and enlarged rectangular joint system along the Mt. Hebgen ridge line portrays well the importance of this phenomenon, and in places coalescing joint solution systems have been dissolved into bowl-shaped valleys, now filled with reddish tan fine grained residue, including abundant clay. The soils aspects of this deposit will be covered elsewhere in the composite report.

A linear zone of small but now active sink holes, with average diameters as great as 10 feet, and depths of about 8 feet, occurs on the east summit area of Mt. Hebgen. Even for this limestone rich area, this development is unusual, and must be carefully dealt with in any human activity.

STRATIGRAPHY

The building blocks for any areal study are, of course, the bedrock units that underlie the area in question. For the most part, the bedrock units of critical interest in the Red Canyon area are all of Paleozoic age, but we shall describe also the Precambrian complex because of its importance in the structural behavior of the area in general.

In summary form, edited especially for this paper, the stratigraphic succession of rocks on the west wall of Red Canyon is as follows: (Note: for more highly technical details on these units, the reader is referred to standard geological reports such as regional papers by Witkind, et al, (1964), or Sloss and Moritz (1951).)

PRECAMBRIAN

The Precambrian complex at Red Canyon crops out in the lower canyon walls near the mouth of the Canyon, Figure 1. In spite of its limited outcrops, it is nevertheless present beneath all other rocks throughout the state and its massiveness is important as an influence on structural trends and patterns. The Precambrian here is all of the very ancient Archeozoic complex, and shows evidence of intensive metamorphism, injection by hot veins and dikes, and a host of other influences of the very ancient geologic past. At Red Canyon, the most common Precambrian rock type is gneiss, with schist a close second. Quartz, feldspar, mica, and iron-bearing minerals are aligned by directed pressure into wavy sub-parallel bands of black and white. Weathering causes the iron minerals to turn reddish brown and this color is common in these rocks. Added to this structure are cracks or joints along which parting occurs. Figure 1 shows the directional orientation of the wavy bands or planes of foliation.

FLATHEAD FORMATION (CAMBRIAN AGE)

This unit rests on the eroded surface developed on the Precambrian complex during the pre-Flathead erosional interval. It consists predominantly of reddish tan to white cross bedded siliceous quartz sandstone, and includes some greenish shaley units in its upper parts, and coarse pebbles, cobbles, and some boulders at its base locally. The material was laid down in an advancing sea, in essence a beach sand, and although moderately resistant, it stands out on the landscape of Hebgen Lake only as an occasional sandstone ledge. The unit is about 125 feet thick, according to Witkind, et al (1964). Except for possible difficulties with the sporadically occurring shale, the Flathead presents few problems to the engineer.

WOLSEY SHALE (CAMBRIAN AGE)

This 150 foot thick unit is the first significantly "weak" formation in the stratigraphic sequence here. It consists of very thin layers green to gray mica bearing clay, but also contains some green glauconite bearing calcareous sandstone, and a few stringers of limestone. Because of its relatively easy erosional characteristics, the Wolsey is stripped back from the Flathead in most instances, and thus forms a bench or tread on the landscape under flat dip situations. Like most shales, it does not allow water to pass through it easily, although it can become saturated with water and is thus a relatively difficult material to cope with from an engineering sense. (See Figure 2.)

MEAGHER LIMESTONE (CAMBRIAN AGE)

This formation is approximately 450 feet thick, and gray in general color. In detail, it is usually in part mottled with a bluish-gray and gold color characteristic, and if inspected closely, fragments of fossil brachiopods and trilobites are common. It is the dominant cliff former in the lower stratigraphic sequence, tending to break off in blocks along somewhat well defined joint plains when undermined by the erosion of the underlying Wolsey Shale.

Although the Meagher is less soluble than other limestones in the area, still it can be predicted that solution is an important modifier of the surface features since they are fluted and pitted where rain water has gathered or run off. The Meagher can be considered as stable under most engineering and construction situations.

PARK SHALE (CAMBRIAN AGE)

The Park Shale is somewhat similar to the Wolsey Shale in lithologic characteristics. It is about 135 feet thick. Primarily, it is a green to brown finely micaceous shale that tends to weather into paper-thin (i.e. fissil) layers that are very soft and non-resistant to erosion. The formation also is intercalated with thin glauconitic sandstone, thin limestone stringers resembling the Meagher, and flat-pebble conglomerate resembling those of the overlying Pilgrim limestone. Geomorphically, it is not difficult to spot, since it forms a bench in the topography, but it is not common to actually find an outcrop of the Park unless it is involved with a landslide or an extraordinarily steep stream cut. When saturated, the Park is one of the most unstable formations in the section and it must be treated with especial respect in any artificial modification project.

PILGRIM LIMESTONE (CAMBRIAN AGE)

The Pilgrim is similar to the Meagher at this location, but unlike the Meagher, it is not a conspicuous raw cliff former. It does form a steepening topographic slope, however, and thus can be located on geomorphic evidence alone. The unit is 300 feet thick. Lithologically, the Pilgrim strongly resembles the Meagher. Its mottling is the same, except for possibly larger mottle blebs, it contains some glauconitic fractions and is more commonly oolitic and conglomeratic than the Meagher. From an engineering standpoint, it is of no particular concern, and it would make good foundation sites for building under most circumstances.

JEFFERSON DOLOMITE (DEVONIAN AGE)

The outcrops in Hebgen Lake area are not sufficiently well exposed to reveal the details of the Pilgrim-Jefferson stratigraphic interval. In this part of Montana, however, thin green shale is present, as well as other lithologies, such as intraformational breccias, algal matt and algal "barrels". One might expect red shale here as well. Except for one outcrop of green shale, we could locate no definite identifiable stratigraphic units in the interval. The Jefferson Dolomite, likewise, is usually a resistant unit where it occurs, but here only sporadic outcrops can be found. Characteristic sugary textured brown dolomite smelling when freshly broken of hydrogen sulfide is the most consistent lithologic characteristic. Breccias, forming resistant ledges in the upper part consist of angular limestone fragments probably derived in the geologic past from the collapse of solution formed caverns. According to Witkind, the Jefferson is about 300 feet thick in the Hebgen Lake area. It is of no particular concern from the engineering standpoint.

THREE FORKS SHALE (DEVONIAN AGE)

This formation is non-resistant and forms a grassy platform if the structural dips are nearly horizontal. It consists of yellowish marl, yellow to light brown siltstone, and toward the top green to brown fissil shale is common. Outcrops are very rare, but float is readily identifiable. It is approximately 150 feet in thickness, and one of the rock types which can be expected to be weak and unstable from an engineering standpoint. However, it is not as vulnerable as the Park Shale to man-made incursion.

MADISON LIMESTONE GROUP (MISSISSIPPIAN AGE)

Two formations comprise the Madison Group; the Lodgepole Formation (below) and the Mission Canyon Formation (above). Together they aggregate 700 feet in thickness on Mt. Hebgen where they form the cap-rock. Certainly the Madison Limestone is one of the most important and conspicuous cliff formers in this part of the Rockies in spite of its great vulnerability to solution by rain and ground water. In color it is mostly "mousy" gray, and for pure abundance of marine fossils such as bryozoans, corals, mulluscs, brachiopods, and the like, the rock can hardly be exceeded. Chert nodules and bedded chert are common about 100 feet from the top of the Mission Canyon and a very prominent collapse breccia occurs consisting of angular limestone fragments contained in a gray to red matrix.

Blocky joints tend to open up any exposed parts of the Madison to solution activity, and the joint width is thus widened and finally becomes small valleys and pockets on the upland topography of Mt. Hebgen and the adjoining ridges. These valleys may contain silt and clay, in part derived as insoluble residue from the formation, and possibly in part from some other source as a lag deposit.

Although the Madison Group is structurally stable, solution collapse is possible in localized areas, as for instance, the northeast summit of Mt. Hebgen. Hence, from an engineering point of view, construction sites should be chosen only after thorough exploratory drilling, and sewage disposal must be approached with great care and preliminary ground water tracer analysis. As mentioned under Geomorphology the dominance of this formation in the upland landscape is probably responsible for the marked lack of overland water flow in the entire area.

AMSDEN FORMATION (MISSISSIPPIAN AND PENNSYLVANIAN AGE)

The Amsden Formation is about 225 feet in thickness, and is more variable in both color and lithology than the underlying Madison Group. The Amsden consists of gray pure limestone of the Madison type, and also includes impure limestone and yellowish marl, some siltstone and red shale. The shale is vulnerable, as is most shale, to water saturation and thus to plastic flow, and the Amsden should be carefully analyzed before engineering projects are

undertaken in association with it. For the most part, the Amsden is restricted to the ridge connecting Mt. Hebgen to Kirkwood Ridge, and here the formation has been mostly removed by erosion. It also occurs on the south side of the Dry Fork of Red Canyon Creek.

OTHER FORMATIONS

Although the remainder of the stratigraphic column does not occur in the area of concentrated study, representative formations of the Mesozoic and Cenozoic are present in the region. Of particular interest here is the name "Red Canyon" since it derives its name from the reddish Woodside Formation of Triassic Age which occurs as a prominent outcrop in the upper waters of the creek. This formation, likewise, contains enough gypsum to make a significant sulfate concentration in the creek in its lower waters. Further, the red clays and silts of this and adjacent units have washed down the creek and contribute extensively to the material comprising the large fan at its mouth on the north shore of Hebgen Lake.

STRUCTURAL GEOLOGY

Structural geology holds important keys to the geological behavior of the Red Canyon area and it must be strongly considered in any man-oriented activity. For true understanding it is necessary to consider the past geological history because recent events, such as the Hebgen Earthquake of 1959, owe many of their characteristics to the imprint of the past. We have already described the stratigraphic building blocks in the Earth's crust which have now been distorted by structural forces.

Two events prior to the most recent few millions of years stand out; they are the structure created in the Precambrian basement rocks over a billion years ago, and the Laramide mountain building episode (i.e. orogeny) of 50 to 60 million years ago. Of the former we know very little except that, as described under the discussion of stratigraphy, foliation planes were created in the rocks, and probably the basement rocks were folded if not faulted in conjunction with, or later than the metamorphism that created the foliation. Foliation, as we see it today, is measurable, and can be mapped like strata in sedimentary rocks. A rapid inspection of Figure 1 will show the reader that the foliation in the lower part of Red Canyon is inclined away from Red Canyon Creek on both east and west sides. This relationship suggests an up-fold or anticline, and its geometry may be the critical factor in understanding the present behavior of faults.

The second event of importance was the Laramide orogeny. Its characteristics are well known throughout the Rocky Mountain region and more or less of similar nature throughout the region. Basically, the Laramide was a compressional episode. The Earth's crust with its relatively thin skin was shortened and compressed into giant wavy masses. At Hebgen Lake, as in most other similar localities, the folds eventually were overturned along their limbs and ruptured in response to continued stress, as thrust faults allowed rocks to be pushed one over the other.

According to Witkind, et al (1964), Laramide compression moved the Madison Range block northeastward along a northwest trending lineament that passes along the north edge of Hebgen Lake. This northwest lineament conforms with many similarly oriented lineaments in this part of Montana. More locally, the compressional zone in the Red Canyon area takes the form of two thrust faulted anticlinal ridges. Hebgen Ridge, as outlined by Witkind, extends northeastward as far as Dave Johnson Creek, and involves both the Wells and Johnson thrust faults. The locus of distortion and rupture northeast of the mouth of Dave Johnson Creek (see Figure 1) skips northeastward to Kirkwood Ridge, whose north bounding thrust passes two miles to the east of Red Canyon fan where it becomes covered by landslides and late age rhyolitic lava.

These structures set the stage for further modification of the area. Common to the history of the Rockies, and many other ranges in the world as well, an episode of post-compressional block faulting was brought about by tensional forces late in the regional orogenic history. Although the origin of tensional forces of this type is not clearly understood, one rather feasible explanation refers to regional upwelling of broad parts of mountainous areas resulting from buoyant forces that resumed when compressional forces were relaxed. Whatever the true explanation, we do know that tensional faults accompanied the regional uplifts, and at Hebgen these tensional faults have been active for at least several million years.

The Hebgen Fault is a tensional fault that bounds (and now forms) the southwest face of Hebgen Ridge. The fault is as close as a thousand feet southwest of the Johnson Thrust, and tends to die out a mile or so north of Dave Johnson Creek. The other important tensional fault in the Red Canyon area is the Red Canyon Fault, which displays relations similar to those of the Hebgen Fault, but which forms the southwest margin of Kirkwood Ridge. Both faults dip generally southwestward at about 75 degrees, and both tend to exploit previous weakness zones such as the planes of more ancient thrust faults and the steeply dipping shaley units on the upright southwest limbs of anticlines created during the compressional phase of folding. In the case of Kirkwood Ridge, the tensional Red Canyon Fault is located along the shaley part of the Amsden Formation for a good part of its length.

The 1959 movements along Red Canyon and Hebgen Faults are only the most recent of a lengthy history of similar movements.

For detailed and extensive description of the various amounts and types of movements involved with the 1959 Earthquake, the reader is referred to articles by Witkind et al, and Myers and Hamilton in U.S. Geological Survey Professional Paper 435. Our discussion here is limited to the facts of significance to an understanding of the Red Canyon area.

The offsets on tensional faults varied during the 1959 Earthquake from a maximum of over 20 feet at Cabin Creek, west of Red Canyon, to the barest minimal trace. Apparently maximum movement coincides in some cases with dips in the bedrock which parallel the direction of shear stress, for when the faults begin to cut across the "grain" of the bedrock, minimal movements

and en eschelon patterns develop along the strike of the faults. Another complicating factor is the amount of and behavior of surficial rock materials approximately above the bedrock fault zone. Although there can be no doubt that the surface offset of these loosely consolidated materials is related in general to the subsurface position of the faults, the actual surface expression resembles a slump scarp in many cases. Actually, it is not unlikely that some of the multiple scarps with associated downhill (southward) movement of surface debris are truly slumps. It would take extensive excavating to reveal the true position of the faults under these circumstances, as fault planes are displayed in bedrock on the surface only in a very few places, notably along the north shore of the lake about four miles west of Red Canyon.

An interesting and important phenomenon in connection with tensional faulting is the tendency for those faults to exploit previous thrust faults as movement planes. It is obvious that the tensional faults closely parallel the regional patterns of the pre-existing thrusts along Hebgen Ridge and Kirkwood Ridge, but where the tensional faults actually coincide with the thrust planes, movement of reverse direction is superimposed on the thrusts. What was "up" on the thrusts is "down" on the tensional faults and vice versa. Considering that Laramide compressional structures at the mouth of Red Canyon tend to parallel Precambrian structures, and that late orogenic, including Recent structures in turn parallel the Laramide, a principle is established which helps to predict the future behavior of faults in this area. Although we are dealing with conjectures which have no absolute basis in fact, it is nevertheless valid statistically to rely on the continuation of patterns established and continually renewed throughout the geologic past. Continually renewed tensional offsetting has accentuated Kirkwood and Hebgen Ridges. Evidence of older recent but prehistoric fault scarps have been described by Witkind where the Red Canyon Fault encounters the Grayling Creek alluvial fan east of Red Canyon. In fact, every major structural valley in this Region, the Gallatin, Madison, Yellowstone, and Helena Valleys, to name a few, are bounded by similar range-front tensional faults, each displaying evidence of movement within the past few hundred thousand years at least, and most with scarps which could hardly be more than a few thousand years old. Thus the Hebgen situation is unique only in that it involved the most recent expression of movement in the region. The broadcast of its earthquakes throughout this region can only serve to emphasize that seismic damage is not at all limited to the immediate area of faulting, as severe seismic shocks are encountered hundreds of miles from epicenters of quakes.

Myers and Hamilton (1964) suggest that faulting may not be the total cause of earthquakes, as the "kinetic energy of the subsiding masses about Hebgen Lake is adequate to explain the earthquake in other terms". This possibility further serves to emphasize the generalized nature of seismic danger throughout southwestern Montana and northwestern Wyoming and withdraws some of the stigma attached to the Red Canyon area as a focal point of seismic danger.

Offset by faulting is the dramatic surface effect of deeper movements which in total are perhaps more important than faulting. Precise leveling in a broad area encompassing the West Yellowstone and Madison Basins shows that the dominant effect in 1959 was downwarping of these basins. In fact, the intervening Madison Range, likewise, was involved with the downwarping. According

to Myers and Hamilton, eastward trends of a structural system developed in the Centennial Valley area, southwest of Hebgen Lake, are being extended eastward across the West Yellowstone Basin to Yellowstone Park.

If the overall movement of 1959 was downward along broad warps, it is by no means certain that downward movement is the dominant trend in the long run. It is more logical to view the superior elevation of local ranges as the result of general upward movements and that extension of the Earth's crust perhaps as a result of total uplift is responsible periodically for relative subsidence of the many basins in this region. It is even conjectured by Myers and Hamilton that the 1959 faults, spectacular as they were, are only shallow slippage zones behaving like giant slump scarps at the north margins of basins whose axes of subsidence lie much to the south of the faulted margins. For instance, measurements indicate that the Hebgen Lake bottom subsided south of Corey Springs (just east of Red Canyon fan) a total vertical distance greater than the offsetting on the Red Canyon Fault a few hundred yards north of the Springs. The fault is thus secondary to and the result of warping in the adjacent basin and not a fundamental deep seated feature in itself. If it were, perhaps volcanic sources would have been tapped, and perhaps the delicate exploitation of pre-existent structures would not have been so precise. We view the faults near Red Canyon as coincident with the margin of a complex subsiding basin with axis of subsidence north of the geographic center of the basin. Thus the south margin of the basin is but gently warped and slightly offset whereas the north is rather severely warped and offset.

Quite a different perspective is presented by Fraser, Witkind, and Nelson (1964) in which the Hebgen and Red Canyon Faults are viewed as old deep seated fundamental tensional faults, the warping of the basin related to downward movement on the south side of the faults, and the extension of the eastward Centennial fault system across the Madison Range and into the West Yellowstone Basin as not valid. Whichever of the concepts is true, the surface map remains essentially the same and the general treatment of the fault system as a constraint in development sites likewise is the same.

GEOLOGIC HAZARDS AND LIMITATIONS

It is more practical to discuss the possible effects of the geologic environment on the Ski Yellowstone development in the vicinity of Red Canyon than to approach the problem from the opposite standpoint. Most features of the geologic realm are simply not to be affected by man-induced activity. A possible exception is the whole aspect of mass wasting.

Six hazard types are proposed here: Mass Movement, Rockfall, Snow Avalanche, Fault Offset, Seiche, and Limestone Solution Collapse. Each type has been further classified into zones which relate to the variance in severity of hazard which that particular type may have. For example, not all areas that have rockfall danger will have the same level of danger. The levels or degrees of hazard must then be categorized. On Figure 2 those zones designated as 1 represent greatest hazard, 2 categories represent lower hazard, and 3 lowest. It must be noted however, that a Zone 1 hazard of a single type is

not necessarily equated to the hazard of other Zone 1 area types. The system is further defined in the Legend of Figure 2. In areas defined as general geologic hazard threats, if actual construction and alteration of the land surface is proposed in a preliminary development plan, summary sheets will be compiled describing any resulting problems and their mitigation.

HAZARDS AND LIMITATIONS

Mass Movement

Mass movement may be defined as the movement of earth materials downslope in the absence of direct fluvial processes. There are many types of mass movement, but basically they may be subdivided into two categories, flowage and slippage. The former includes such activity as solifluction, creep, and mudflow, while the latter involves brittle failure of the mass which behaves initially as an elastic body. Slumping and rockslide are typical examples of the latter type. Brittle failure causes rockfall, a separate category to be discussed in the next section. The others will for convenience be grouped together as mass movements and landslides. These mass movements take place at various rates which depend upon the amount of water available, slope angle, and types of constituent materials. The rates vary from imperceptible to very rapid. Clay-rich earth is particularly susceptible to mass movement in the Rocky Mountains, as it becomes easily mobilized when wet or highly disturbed. Shales and shaly marls are rock types with a predominance of clay flakes in their make-up, and they weather easily to incohesive masses of clay of unstable characteristics. Mountain slopes underlain by these rock types will thus be most susceptible to mass movement.

Climate is a controlling factor relating closely to weathering and breakdown of shales. It also controls the availability of water for mobilization. The Mt. Hebgen area has a climate that allows for the initiation of mass movement processes. These landslides are shown on Figure 1 and designated by symbol, Qls. There is no reason to believe that these slides mark all the mass movement that will ever take place in the study area; instead they point strongly to the possibility that more will occur in the future when conditions are ripe. A study of the landslides shows all but one to have originated in the Park Shale; the remaining started in the shaly zone of the Amsden Formation. These two units appear to be the most landslide-prone in this part of the stratigraphic section, but two other shaly units should be noted in spite of the fact that to date they have not failed in the study area. These are the Wolsey Shale and the Three Forks Shale. Although stable to date, the lithologies of these formations suggest that they would have potential for mass movement failure. Three mass movement hazard levels may be delineated:

1. Recently active mass movement with extreme limitation to construction: Even if inactive, these would be easily reactivated if undercut severely, if stress were applied in excess of their cohesive strength, or if the material in question is exposed to ingress of excessive water. The potential for movement here should be carefully weighed before any disturbance is made to the natural equilibrium. The best solution would be to avoid them altogether, but if building must take place on a landslide the construction should be done as far removed from the axis of the slide as feasible.

Use of heavy equipment should be limited as much as possible, as this would apply a great stress to unstable material. The drainage of the landslide mass as a whole, or around any foundation set in a landslide must be absolutely effective if the weight of the installation is to be supported correctly and not cause slow creep over the years. The hazard presented by these landslides to construction cannot be completely mitigated in most cases.

2. Rock units now stable but presenting serious hazard of mass movement if disturbed or wetted: This zone is congruent with the locations of the Park Shale and the Amsden Formation. The Amsden Formation crops out along the N-S ridge of Mt. Hebgen but its lithology here consists of limestone and bedded chert, both stable. It does not outcrop in significance anywhere else on the mountain. But the Red Canyon fault exploits a weak shaly zone in the Amsden on Kirkwood Ridge and the east face of Red Canyon. Its presence should be noted but it poses no hazard to the development, because of its location. The Park Shale does outcrop along the east face of Mt. Hebgen and deserves some attention. As noted above it has already failed in several locations and may fail in others. Springs appear to have controlled the location of previous failure but conceivably the springs resulted after the slides. Thus special precautions must be taken where the Park is exposed to much water; the major springs that are found on the SE face of the mountain, may make that particular area most hazardous to building. Mitigation of the hazards inherent in the Park is possible using the same guidelines as those for Zone 1. To reiterate, the Park Shale should be avoided for construction sites if possible.

3. Rock units now stable but presenting moderate hazard of mass movement if disturbed or wetted: The Wolsey Shale and the Three Forks Shale comprise this zone. Both formations have been stable to date, and shall probably remain so in the future, but in the past they have not been subjected to the stresses of construction and heavy buildings. Because of the very nature of the lithologies involved, these units should be treated with respect. If possible they should be avoided, but if construction must proceed on them, the procedures outlined for construction mitigation should be followed.

ROCKFALL

Rockfall results from brittle failure of rock along discrete weakness planes. Joints, bedding, shear zones and the like are typical of these planes and common in nearly every rock outcrop. The failure is caused by a change in the delicate balance between the force of gravity tending to pull the mass downward and the cohesive forces holding the mass on a steep slope. The force of freezing water, or the shaking of an earthquake are two such outside forces that are effective, particularly if the rock bodies are already delicately held in position. A much larger total volume of rock is apt to fall during the short duration of an earthquake than during the relatively longer interval between major quakes. An obvious first requirement for any rockfall to occur is the exposure to slopes greater than the angle of repose of the materials involved. This varies depending upon the lithologies and climate of an area, but it is generally about 35 degrees. The greater the angle of slope in excess of that figure the greater the hazard from rockfall.

In the study area rockfall may be considered as a serious hazard as many slopes are well over the angle of repose. The area also falls in a zone of high seismic activity. As the danger of rockfall increase with slope angle and also with the total number of vertical feet imposed by the slope, several levels of rockfall hazard must be delineated. For example, a vertical cliff 10 feet high is not as apt to produce rock falls as a vertical cliff 100 feet high. The runout zones beneath cliffs, likewise, may be relatively low in slope but may be targets for a rain of rock material from above where the kinetic energy is enough to cause rolling onto lower slopes. On Figure 2 three hazard levels are delineated only on the basis of probability.

In mitigating rockfall hazard, the most effective safeguard is to avoid the areas as building and activity zones. However, it may be statistically valid to allow activities involving infrequent passage particularly if judgment can be applied when planning such passage. To chance a building in such a situation would not be prudent in the long run, but to allow a cross country ski trail to pass beneath a cliff in mountainous terrain is a frequently tolerated situation. The skills of mountaineering and ski touring pit the climber or tourist against the hazards of nature to allow optimum possibility for negotiating the terrain in spite of the hazard involved. Common mountaineering knowledge would call for the leader to avoid exposure during rapid melt, during rapid freezing, heavy rain or snowfall, but the statistics of earthquake occurrence suggest that the chances of an earthquake catching a party beneath a cliff are of low probability. Nevertheless, warning signs and educational displays would be advisable if a public agency or corporation is to discharge their duties to the public properly.

Rockfall zones are classified according to the following scheme:

1. Zone of extreme hazard during an earthquake and moderate danger at other times. This zone falls primarily outside the area of intensive development, and should not pose much of a problem to the developer other than an awareness of its presence. This zone follows Kirkwood Ridge, the head of Red Canyon, and the northeast wall of Red Canyon. Another small area of Zone 1 occurs at the point where Dave Johnson Creek enters its fan. No building should be attempted in these zones and skiers and hikers should be warned of the hazard in these areas. In the winter the danger decreases because of snow, but the hazard is not non-existent.

2. Zone of serious hazard during an earthquake and low danger at other times. This zone is found along the east face of Red Canyon, the south face of the ski mountain, a few minor zones elsewhere on the mountain, and along Dave Johnson Creek. These areas should be avoided for building if possible, and skiers and hikers should be warned of their presence. If a ski trail passes through Zone 2, fences might be constructed on the uphill side of the trail to channel people through and prevent uphill venturing at these localities.

3. Zone of moderate hazard during an earthquake and very low danger at other times. This zone is mapped at many locations in the study with two large areas on opposite sides of Red Canyon. If easily feasible Zone 3 should be avoided, and again hikers and skiers should be warned of the hazard.

SNOW AVALANCHE

Snow avalanche analysis for the most frequented parts of any ski development should fall under the scrutiny of individuals trained in the art of prediction and control, and locally oriented to the conditions normally experienced in the area in question. The slopes of the east flank of Mt. Hebgen are not unusual in any avalanche sense; in fact, for a major ski area, they are predictably safe under most conditions. Still, avalanches have been recorded on slopes as gentle as 24 degrees under special conditions such as high rate and duration of snowfall under the influence of moderate to strong winds. Since there are many slopes here greater than that, they will have to be watched and checked under severe conditions and reduction measures taken on some slopes where advisable and prudent. The presence of trees is not necessarily a controlling negative factor. The most likely slope angles for snow avalanches range between 35 and 45 degrees.

Some slopes in the Red Canyon Area do show evidence of extensive active modern snow avalanching. Fortunately, these are all located outside the zone of development and formal downhill skiing. They do fall within a zone which would normally be frequented by cross country skiers, however, and warnings may be necessary to this clan of newly enthusiastic sportsmen. Essentially, the active snowslides of today coincide with zones of dangerous rockfall. These include areas along the east wall of Red Canyon clear to the spot where Red Canyon Fault is crossed by Red Canyon Creek, a zone more or less coincident with the entire south exposure of Kirkwood Ridge and extending to the valley bottom of the Dry Fork of Red Canyon Creek, and a questionable zone on the north side of Dave Johnson Creek from its mouth upstream for about one mile. Tree patterns here suggest past avalanche activity, and only continued observation under avalanche conditions will turn up workable formulae for restrictions and control. Many seasoned cross country tourists are anxious and willing to pit their judgment and skill against snow avalanches and get their "kicks" in the out of doors from taking some chances if the risk is not too great. However, for the uninitiated and the unsuspecting tourist, particularly the younger set, the Corporation and the U. S. Forest Service may have an obligation to set stringent regulations with or without formal patrol work. Care should be exerted, however, so as not to overly restrict this impressive ski touring terrain, since that might dampen to an unnecessary degree the enthusiasm and the opportunity for the general public to enjoy this growing sport.

SEICHE

A seiche can be defined as the oscillation of water in a basin. Seiches generally result in a lake basin when a strong wind that has been blowing for several days finally subsides. The wind over a period gradually piled water up in the upwind portion of the basin. When the wind subsided the oscillation of water in the lake began; this is the seiche. The period of oscillation depends on the parameters of the lake and the strength and duration of the wind. This may vary from a period of a few minutes to one of several hours. While wind is the most common cause of the seiches, other more catastrophic

phenomena may cause them. An earthquake which either lifts or depresses all or part of a lake basin will cause a seiche. A seiche of this type is apt to be much greater than those brought about by wind. Flooding and even permanent submersion can result. In determining the area that might be affected by earthquake induced seiche Witkind (1972) sets forth 3 assumptions that must be used: 1) A major local earthquake takes place, 2) the lake will be at high water mark at the time of the earthquake, 3) the early seiches produced will rise 30 feet higher than the water mark. Using these assumptions, which were in fact based on the seiches in Hebgen Lake produced by the 1959 earthquake, and data on permanent submersion around the north shore of Hebgen Lake, two zones of limitation may be drawn up:

1. Zone of possible permanent submersion. This zone is between the level of the reservoir and a contour 10 feet above the high water mark of the lake. This level is determined by data obtained from submersion in the 1959 earthquake. Should another earthquake occur the submersion may be greater or less than this amount, but the 10 foot level is the best figure available. As with all seismic risks we are dealing with a probability and the safest way to mitigate against the hazard is to avoid it completely. Lakeshore development will surely take place but should be limited to only those buildings necessary for lake use facilities such as marinas. The buildings should be built to sustain the full impact of a 30 foot seiche (not to be confused with a wall of water 30 feet high). It is important to remember in the mitigation of hazards that result from catastrophic events that the only sure alternative is total avoidance of the hazard zone. As this is impossible less effective mitigating procedures have to be used, and there will always be some hazard.

2. Zone of greatest seiche flooding hazard. This zone extends from the shore line of the lake to a contour 30 feet above the high water line of the lake. It would be best to limit construction in this zone, but what construction does take place should take into account the possibility of flooding.

LIMESTONE SOLUTION COLLAPSE

Limestone is rock composed mainly of calcium carbonate - $CaCO_3$, which is soluble in acidic water. Rain water (H_2O) combines with carbon dioxide (CO_2) in the atmosphere to form carbonic acid (H_2CO_3) and thus rain water becomes slightly acidic. Rain can then dissolve limestone, and if the limestone is not porous or permeable the water can only soak into the limestone along joints and bedding planes. Water traveling along these planes gradually dissolves the limestone along the planes making conduits which become larger with time. The end result is a complete underground drainage system, with a great subsurface potential for the removal of limestone. If a large volume of limestone is removed collapsing is apt to take place. The prerequisites for the formation of this hazard then are the presence of a dense impermeable nonporous limestone, good joint and bedding plane systems, and abundant rainfall. In the Hebgen study area the Madison limestone is ideal for the formation of underground drainage, but apparently for some reason the other limestones are not too affected. Rainfàll is not generally great so extensive limestone solution and the accompanying geomorphic expressions are not highly developed. But hydrologic

data shows that underground drainage in the area may be highly developed. And associated solution collapse features have been developed in one area. Two hazard zones may be set forth in the limestone solution collapse category. Neither is particularly high risk in nature, but they should nevertheless be noted:

1. Zone containing active collapse features. This zone is limited to the top of Mt. Hebgen and is also restricted to the Madison Limestone. In the zone there are several collapse sinks as noted in the geomorphology section of the report. These can be considered active, and conceivably any spot in the zone could collapse. While these features are not large, it would be best to stay clear of them in building as they could undermine foundations. Exploratory drilling to insure solid bedrock under a planned building might be advisable.

2. Zone with potential for development of collapse features. Much of the NS ridge of Mt. Hebgen is underlain by slightly dipping limestone of the Madison and Amsden formations. Both of the lithologies are good for solution collapse development, and enlargement of joints at the surface reinforces the idea that underground drainage plays a major role. As yet no collapse features were noted, and none may be developed in the life of the project. No geologic restrictions should be placed on building in this zone other than the periodic monitoring of the bedrock near any buildings.

FAULTING AND WARPING

The limitations due to faulting and warping are founded on observations described in the Structural Geology section of this report. We view these limitations as among the most severe in the Hebgen region. Simply stated, development on or directly adjacent to faults of tensional origin showing movement during the 1959 Earthquake, or in recent prehistoric time would be inadvisable, even though buildings offset by faulting of this type might not be completely demolished. It is within feasible risk to construct such projects as parking lots and roads in these zones, however, even though any movement would be expected to offset pavement, tilt or even tumble cars while parked, etc. We feel that rockfall in connection with faulting and involving sites beneath overtowering cliffs is a greater danger than the threat by faulting offset alone. There have been no recently recorded fault offsets in North America with movement exceeding twenty feet, and in no case is the probability of cataclysmic opening of bottomless gashes in the Earth's crust a valid possibility, despite some popular and overblown rumors to that effect. The Figure 2 map locates the fault planes as they are known.

Since there has been a tendency for offsetting (i.e. faulting) to be located along previously active but compressionally dormant fault lines, the exact location of former faults has become significant and important in a limitations sense. If these old fault lines have not been exploited by more recent movement, the rank of limitation is reduced to secondary importance. Compressional faults of the Laramide Orogeny will not today present danger from renewed compressional movement, as compression in the purest sense is not a characteristic of the

phase of Post-Laramide mountain building in which the Northern Rockies are now involved.

The most difficult question regarding development vs. faulting involves a zone across the Red Canyon fan which falls directly in line with the projection of the older Red Canyon tensional fault system. Witkind, et al (1964) show the mapped trace of the older Red Canyon fault projecting toward the fan, and abruptly terminated by alluvium of the fan east of the present creek channel. There is no direct and continuous linkup of the fault trace to the Hebgen Fault to the west. Presumably the Hebgen fault resumes the offset relationship several miles west of the fan, however, it is important to note that the westward vector of projection of the Red Canyon fault toward the fan is not based on strong field evidence, but two small scarplets produced by the 1959 event do extend westward toward the edge of the fan.

The most compelling evidence for modern trends of the Red Canyon Fault is the curved en eschelon swing of 1959 scarps and scarplets from an eastward to a northward strike around the east portal of Red Canyon. Thus, the Red Canyon Fault followed an old line of movement in 1959, eventually swinging around to coincide with the upright southwest limb of the Kirkwood Ridge Anticline. It seems valid to us to assume that where the Red Canyon Fault terminates along the west end of the Kirkwood Anticline, the basic tensional stress is transferred once again southward to the Hebgen Fault, which carries then for many miles further west. Since the stress patterns have been thus expressed in the past and present, it is realistic to say that this will be the trend of the future, and thus, the Red Canyon Fan will probably continue to be spared the fate of offset.

In spite of the statistical probabilities that the Red Canyon Fault will avoid the lower Red Canyon fan in the future as it has in the past, and that stresses in the area are already sufficiently relieved to preclude movement within the life of the Ski Yellowstone development, we have projected a low risk offset possibility zone across the Red Canyon Fan opposite the place of deviation of the fault. We believe it would be in the responsible interest of the corporation to err on the positive side of this difficult prediction and not take chances building where there is even a remote probability of offsetting along the fault system, even though the recent release of stresses makes this area possibly among the more stable at present in the entire region.

In addition to the actual fault offset hazard, a more widespread hazard related to shaking associated with earthquakes is to be expected in a seismic episode such as occurred in August, 1959. On a broad scale regional basis no single location in the study area is apt to be shaken harder than any other. For this reason this hazard is not mapped. Relatively destructive shaking may be initiated not only by movement along the Red Canyon and Hebgen faults, however, but also from movements associated with any of the fault systems recently active in Southwest Montana, and the adjacent areas of Idaho and Wyoming. On the Modified Mercalli Scale, which rates the damage done by an earthquake on a scale of 1 - 12, the highest hazard rating in the Ski Yellowstone area would be related to movement on the Red Canyon or Hebgen faults, or on newly initiated faults located within a few miles of Red Canyon. The damage rating could

conceivably exceed the Modified Mercalli No. 10 (some well built structures destroyed; most masonry structures destroyed, rails bent, landslides considerable) recorded along part of the north shore of Hebgen Lake during the 1959 earthquake.

The damage done by the 1959 earthquake diminished rapidly away from the epicentral area, with West Yellowstone receiving a rating of No. 7 (little damage to well designed structures, serious damage to poorly designed structures). However, the sharp decrease leveled off at 7, areas as far away as Harrison, Montana also receiving a 7 rating, while ratings of 6 (felt by all, damage slight) continued into eastern Washington.

Two generalizations can be made from these observations: 1) for a structure to receive near total destruction it must be located near the epicenter of a severe earthquake; 2) minor damage to buildings, etc., can be sustained in areas over a hundred miles from a severe earthquake.

The possibility that the Ski Yellowstone development would be inflicted with a 10 or greater damage rating is low for the life of the project and would require major movement along any of the three faults mentioned above, or on faults located within the same radii from the development area. The possibility that a 6 or 7 rating damage might be inflicted is much higher, considering recently active faults within a 200 mile radius of the development site.

PRESENT STATUS, PREDICTIONS, AND CONCLUSIONS

As an aid to the formulation of judgment statements about the effects of Ski Yellowstone on the natural environment and the constraints which the natural environment will impose on the development, we present herewith an outline summarizing the salient geologic aspects under present and predicted future use.

PRESENT USE

Moderate seasonal recreational activity is enjoyed today in the Red Canyon area. This activity could hardly involve more than a few thousand man days/year at the most. Logging appears to be the only non-recreational industry of any importance. It is possible to derive qualitative opinions as to the interactions of man and environment under these circumstances.

1. Ski touring, hiking, fishing, hunting, snowmobiling, and camping comprise the principal recreational use today. From a geologic sense, these recreational activities normally won't threaten the environment. The environment does pose some threat to these activities, however. Rockfall, snow avalanches, and landslides could be precipitated either naturally or through the interaction with man. The recurrence of tensional faulting in the area could disrupt campsites or overturn equipment, or indirectly set loose rocks, avalanches, or landslides. Since major seismic events caused by faulting are infrequent at a given area, and since the 1959 event must

have relieved stress and thus stabilized the local area for a time, local faulting of the magnitude of 1959 is unlikely for several hundred years hence.

2. Clear-cut logging may cause some change in the natural geological equilibrium inasmuch as snow accumulation in clear-cuts is increased, and as a result snow melt and rapidity of runoff in early parts of the melting season are also increased. The end result could be increased siltation of streams (of which there are very few) and the possible seasonally increased saturation of certain landslide-sensitive formations. Again, we are not particularly impressed that the present clear-cutting has brought about a significant modification of the geologic regime and would tend to ignore it unless major clear-cutting is initiated.

PREDICTED PEAK LOAD EFFECTS

With a maximum predicted winter peak load of 5,000 skiers per day, and a summer peak load of from 3 - 4,000 people per day, there will be environmental effects on the geological situation that certainly exceed those of the present. Again, from a qualitative point of view, the same triggers to sliding phenomena are to be expected as were predicted above under the present conditions, with perhaps an increase in this activity. It would not constitute a major threat to the environment, however, and in some cases there may be less effect since some steps will be taken to reduce the danger of avalanches, to advise where safe and unsafe climbing and touring routes are, etc.

We can say that installations of the many lifts, housing units, ski trails and similar additions will bring about changes in siltation and changes in land stability if not carried out with full steps to mitigate the effects of these installations on the environment. The geology of the area is such that indiscriminate disposal of waste might have an immediate and disastrous effect on the underground and surface water systems alike, so closely is the rock type associated with hydrology. But we have no fear of water contamination if the proper engineering and sanitary steps are taken. Hence, the interaction of man on geologic environment, and vice versa is forseeably controllable, and not a serious threat to the success of the development or offsite situation.

CONCLUSIONS

This paper has examined the bedrock stratigraphy and structure of a typical northern Rocky Mountain area. Its only really extraordinary geologic aspects are recently active faults and warps with associated seismic shaking. By analogy, even this phenomena is to be expected throughout southwestern Montana within the time span of the last few thousand years. We conclude that the geology imposes some constraints as to construction and use, but as long as the developers are respectful of these constraints and work around them, or design for them, there appear to be no insurmountable difficulties. The principal areas of geologic sensitivities involve, in order of ranking from most threatening to

least; 1) danger from fault offset, 2) danger from rockfall due to seismic shaking or human influence, 3) danger from landslides triggered by natural or human causes, 4) danger from snow avalanches on offsite areas, and on a limited few onsite areas, 5) danger from flooding caused by a seiche in Hebgen Lake, and 6) danger from solution collapse within a very limited zone on the east summit of Mt. Hebgen.

Because of the complexities involved with the appraisal of fault hazard in the Red Canyon area, and because of the sensitivities generated in the public mind by the 1959 Earthquake, it is important to reassure the reader that development such as proposed by Ski Yellowstone is a feasible enterprise. Statistics indicate that frequency of faulting is of the order of 100,000 years and thus that faulting will predictably not seriously threaten Red Canyon within the expectable 200 year life of the project. This prediction does not invalidate the advisability to avoid construction in close proximity to recently active fault lines or rockfall areas, or the recommendation to limit construction to one story frame types in the "low risk fault projection zone" indicated on Figure 2. It is obvious that all buildings in the entire tri-state region be built to conform with an engineering code allowing for Modified Mercalli scale earthquake shocks of magnitude 7. If the above conditions are met, and every indication appears that they will, disastrous effects will not occur even if faulting did reoccur within the life of the project.

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View northward toward Kirkwood Ridge from the Dry Fork of Red Canyon Creek. Note dissected alluvial fan in foreground, the Red Canyon Fault scarp halfway up ridge, and the towering Madison Limestone cliffs above the fault line.

Recent collapse sinkhole in limestone rubble just east of the summit of Mt. Hebgen.

ILLUSTRATIONS OF GEOLOGIC RELATIONS IN THE RED CANYON AREA.

View southeast from summit of Mt. Hebgen showing Red Canyon Fan (left) and looping morainal peninsula formed by the terminal activity of a piedmont glacier of Bull Lake age with origin in Yellowstone Park.

Rolling topography on gently westward dipping Madison Limestone rock typical of the summit area extending from Mt. Hebgen to Kirkwood Ridge.

ILLUSTRATIONS OF GEOLOGIC RELATIONS IN THE RED CANYON AREA.

Landslide in surface rubble and moraine at east portal of Red Canyon Creek just north of Highway 287. The slide originated along the Red Canyon fault in 1959 as a result of both shaking and the discharge of an above average amount of water in springs near the willows and pine along the upper slump scarp. The underlying rock type is Cambrian Park Shale.

ILLUSTRATIONS OF GEOLOGIC RELATIONS IN THE RED CANYON AREA.

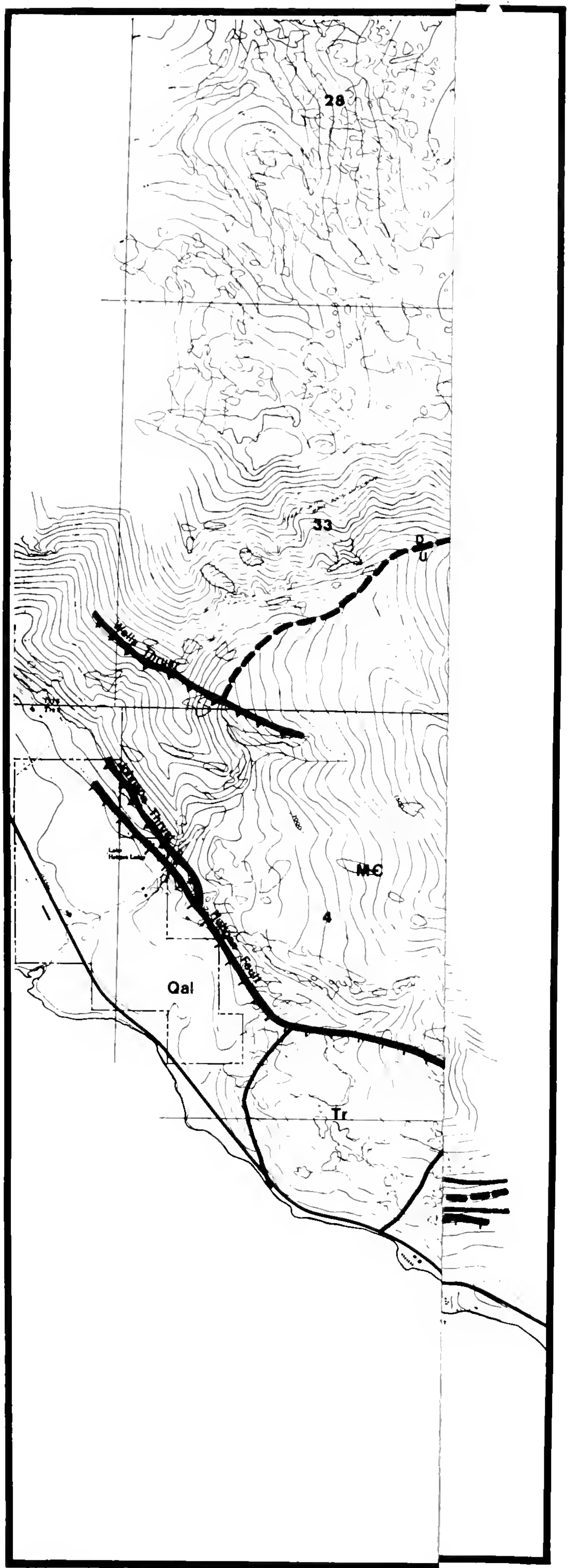

FIGURE 1

ENVIRONMENTAL SUMMARY

PRIMARY STUDY AREA

BEDROCK GEOLOGY INVENTORY

BY: J. MONTAGNE AND R. H. PAGE

STRATIGRAPHY

QUATERNARY	Qal	ALLUVIUM
	Qgb	GLACIAL BOULDERS
	Qls	LANDSLIDES OF VARIOUS TYPES
TERTIARY	Tr	RHYOLITE WELDED TUFF AND FLOWS
MISSISSIPPIAN	Mm	MADISON LIMESTONE GROUP
DEVONIAN	Dtf	THREE FORKS SHALE FORMATION
	Dj	JEFFERSON DOLOMITE FORMATION
M€ DEVONIAN AND CAMBRIAN STRATA UNDIVIDED	€pl	PILGRIM LIMESTONE FORMATION
	€p	PARK SHALE FORMATION
CAMBRIAN	€m	MEAGHER LIMESTONE FORMATION
	€w	WOLSEY SHALE FORMATION
	€f	FLATHEAD SANDSTONE FORMATION
PRECAMBRIAN	P€	UNDIFFERENTIATED META-MORPHIC BASEMENT ROCKS

APPROXIMATE FORMATION CONTACTS

FAULTS

D U — COMPRESSIONAL (THRUST)
BARBED ON SIDE ORIGINALLY UPTHROWN
DASHED WHERE UNCERTAIN
REACTIVATED AS TENSIONAL FAULT BEFORE 1959.
U, UPTHROWN SIDE, D, DOWNTHROWN SIDE

D U — TENSIONAL (NORMAL)
DASHED WHERE UNCERTAIN, NOT RECENTLY ACTIVE
U, UPTHROWN SIDE, D, DOWNTHROWN SIDE

1959 FAULT OR SLUMP SCARP, HACHURES ON DOWNTHROWN SIDE

12 — STRIKE AND DIP OF SEDIMENTARY BEDS

34 — STRIKE AND DIP OF FOLIATION IN METAMORPHIC ROCKS

AUGMENTED AND MODIFIED FROM WITKIND ET. AL., (1964), U.S.G.S. PROFESSIONAL PAPER 435

SKI YELLOWSTONE

SKI YELLOWSTONE INC.

WEST YELLOWSTONE, MONTANA

SCALE: 1" = 2000'

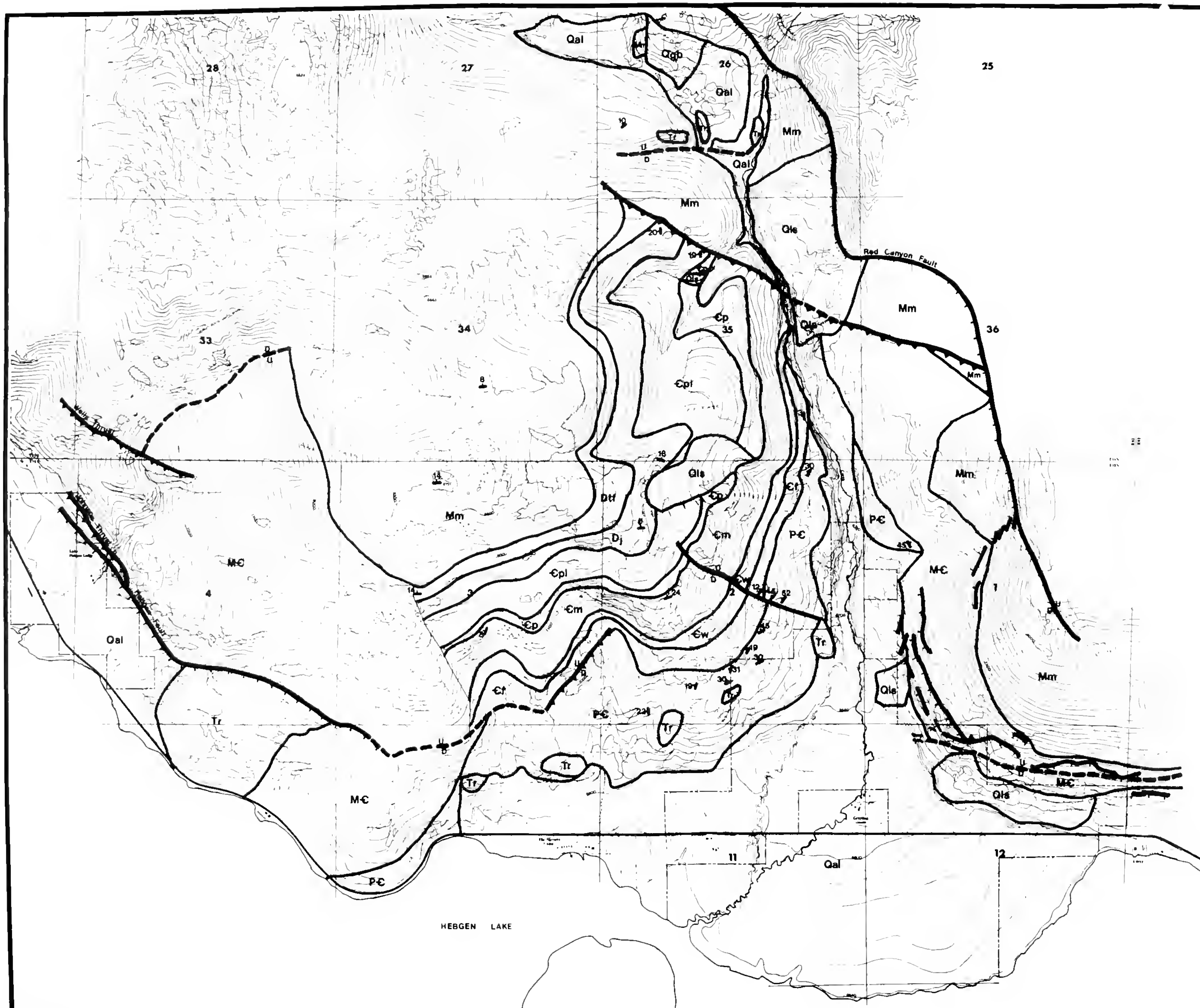

FIGURE 1

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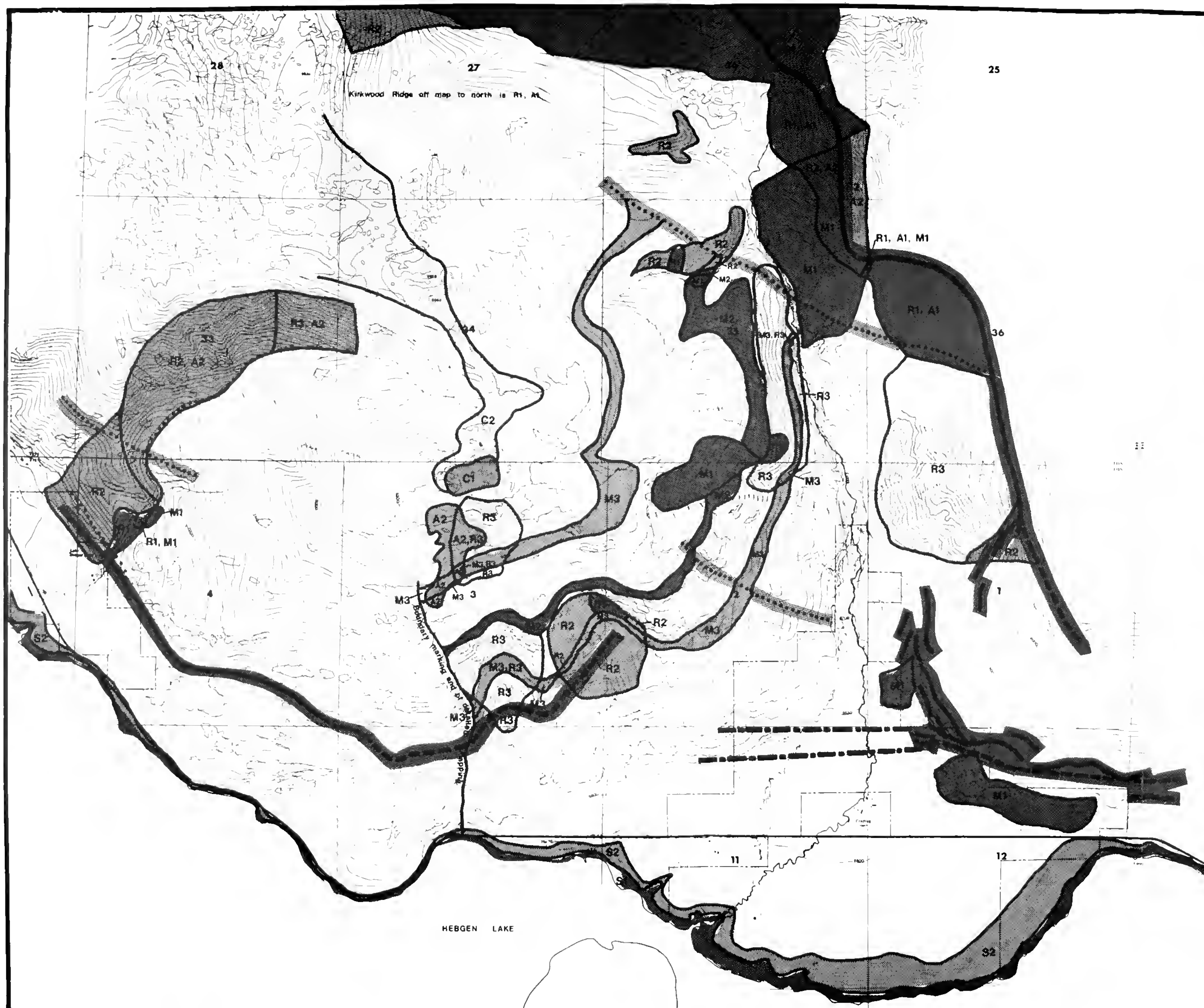

FIGURE 2

ENVIRONMENTAL SUMMARY

PRIMARY STUDY AREA

GEOLOGY
DEVELOPMENT LIMITATION ZONES

BY J. MONTAGNE & R. H. PAGE

LIMITATION

SEICHE

- S1 ZONE OF POSSIBLE PERMANENT SUBMERSION
- S2 ZONE OF GREATEST SEICHE FLOODING HAZARD

ROCKFALL

- R1 ZONE OF EXTREME HAZARD DURING AN EARTHQUAKE & MODERATE DANGERS AT OTHER TIMES
- R2 ZONE OF SERIOUS HAZARD DURING AN EARTHQUAKE & LOW HAZARD AT OTHER TIMES
- R3 ZONE OF MODERATE HAZARD DURING AN EARTHQUAKE AND VERY LOW AT OTHER TIMES

SNOW AVALANCHE (UNDER EXISTING TREE COVER)

- A1 ZONE OF EXTREME HAZARD
- A2 ZONE OF LOW TO MODERATE HAZARD
- A3 ZONE OF VERY LOW HAZARD SEE TEXT

MASS MOVEMENT

- M1 ACTIVE MASS MOVEMENT, WITH EXTREME LIMITATIONS TO CONSTRUCTION
- M2 ROCK UNITS NOW STABLE BUT PRESENTING SERIOUS HAZARD OF MASS MOVEMENT INITIATION IF DISTURBED OR WETTED
- M3 ROCK UNITS NOW STABLE BUT PRESENTING MODERATE HAZARD OF MASS MOVEMENT INITIATION IF DISTURBED OR WETTED

LIMESTONE SOLUTION COLLAPSE - LOW RISK

- C1 ZONE CONTAINING ACTIVE COLLAPSE FEATURES
- C2 ZONE WITH POTENTIAL FOR DEVELOPMENT OF COLLAPSE FEATURES

FAULTING OFFSET

- EXTREME POSSIBILITY OF OFFSET
- MODERATE POSSIBILITY OF OFFSET
- LOW RISK FAULT PROJECTION ZONE (SEE TEXT)
- LOW POSSIBILITY OF OFFSET

DEGREE OF LIMITATION

- HIGH
- MODERATE
- LOW

SKI YELLOWSTONE

SKI YELLOWSTONE INC.

WEST YELLOWSTONE, MONTANA

SCALE 1 : 2000'

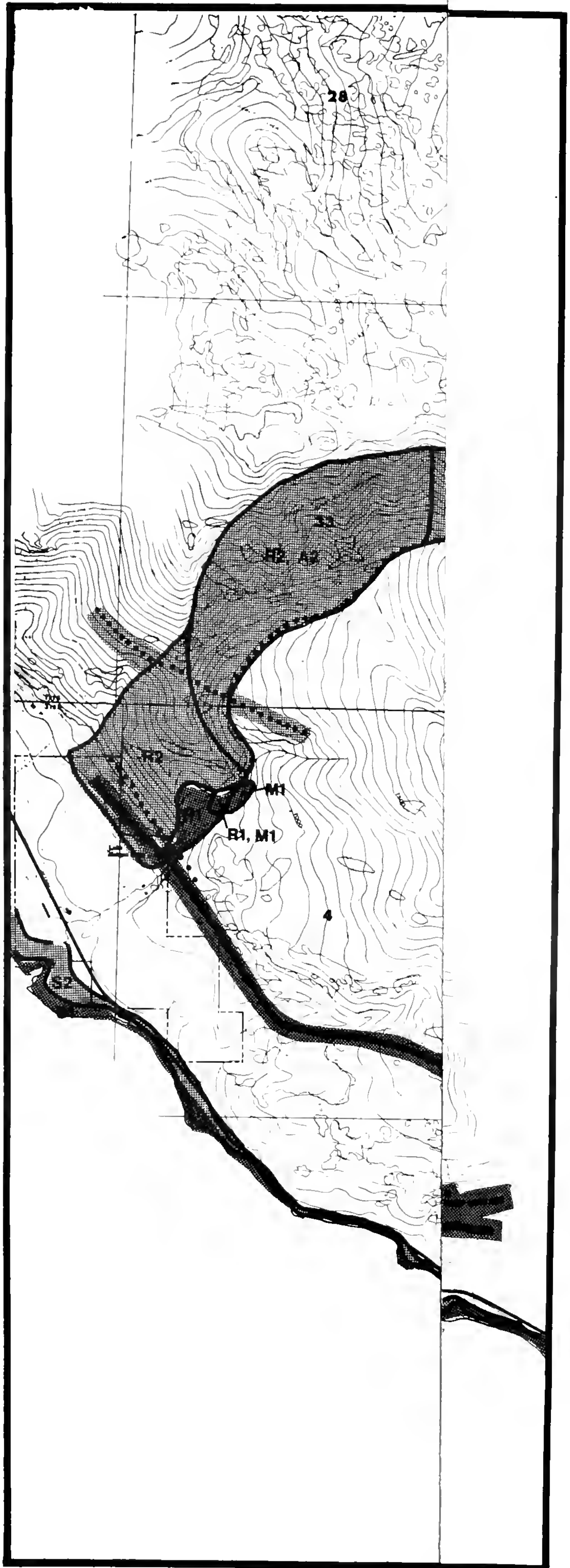

FIGURE 2

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SKI YELLOWSTONE

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WEST YELLOWSTONE, MONTANA

SCALE. 1 : 2000'

SOILS AND SURFICIAL GEOLOGY INVENTORY

Clifford Montagne

INTRODUCTION

This work is part of the Environmental Inventory being done by the Hebgen Research Team for Ski Yellowstone, Inc. It will be used for development evaluation by the U. S. Forest Service and for planning by Ski Yellowstone's planners. The goal of the work and this report is to inventory and evaluate the development area from the standpoint of soils and surficial geology. In this report, combined soils-surficial geology mapping units are described. The land is evaluated for suitabilities or constraints for uses such as road building, dwelling construction, ski lift construction, and ski trail clearing.

GEOGRAPHIC SETTING

The Hebgen Lake area lies within the Northern Rocky Mountain Physiographic Province of the United States. It is a geomorphically young area with high relief. The soils and surficial deposits are primarily products of rapid slope erosion and deposition. The natures of these materials are strongly influenced by topographic position and parent material. Other sections of the Hebgen Research Team Report describe in detail the area's biological, geological, climatological and hydrologic setting.

ACKNOWLEDGEMENTS

The writer thanks Hans Geier and Fred Pack of Ski Yellowstone for logistical help. The other members of the Hebgen Research Team contributed to the interdisciplinary nature of this report; especially John Montagne and Brent Haglund. Completion of the work would not have been possible without the assistance of Bob Pack and Bob Page.

PREVIOUS WORK

The writer knows of no previously completed soil survey work in the Mt. Hebgen - Red Canyon area. Some soils investigations have been conducted nearby, mostly by geologists attempting to use soils for age correlation of Quaternary surficial deposits. The most comprehensive soils work completed in a nearby similar area was that of Olsen, Leeson and Neilsen (1971) in the Gallatin Canyon. The geologic map of Witkind et al, (1964) was very useful for understanding the bedrock units occurring in the study area.

METHODS OF STUDY

Time constraints and study objectives eliminated the feasibility of a standard agricultural soil survey. Emphasis was placed on soil and surficial material descriptions useful for impact evaluation.

Mapping was done on color aerial photos during foot field traverses. Much of this was done in conjunction with the geological study. One or more sites representative of each mapping unit were examined and described in detail. The lab data used for the engineering interpretations was generated from samples collected at each representative site.

SOILS - SURFICIAL GEOLOGY MAPPING UNITS

In the Mt. Hebgen - Red Canyon area the surficial mantle consists of material that is either colluvial (slope debris), alluvial (stream deposit), or residual (weathered in place). Much of this material weathered and accumulated during the Wisconsin Glaciation when hillslope processes were more active than at present. On the steeper slopes the ongoing downslope movement of soil and rock debris has obliterated most soil horizon development. Many of the alluvial deposits, at lower elevations and lesser slopes, have been stable long enough to develop soil horizons. Thus each mapping unit has its distinctive properties as a surficial material while only some units have experienced pedological soil horizon development.

Since a separate slope map has been made for the study area, slopes were not mapped as an integral part of the soils-surficial geology units. Many of the construction limitation or suitability interpretations do not take slope into account. This was done because ski area construction, by nature of the terrain, must be done on abnormally steep slopes.

Following are descriptions of each mapped soils - surficial geology unit. While reading these descriptions, one should also refer to the Soils and Surficial Geology Map for mapping unit locations and to Appendices I, II, and III for detailed soil profile descriptions, lab analyses and land use interpretations. Technical terms are defined in the glossary.

ALLUVIAL UNITS

Al - fc Fine clayey alluvium

This material comprises the lower part of the Pinedale (Wisconsin Glaciation) age alluvial fan of Red Creek from its mouth south to the shore of Hebgen Lake. This alluvial fan of consists of deep red loams and clay loams deposited

by Red Creek. The red clayey material is derived from the Jurassic Woodside Formation shale which outcrops in Red Canyon north of Kirkwood Ridge. Due to the fan's low physiographic postion and original clayey texture, a grassland type dark, rich mollic epipedon underlain by a Bt horizon of clay enrichment has developed. Beneath the Bt horizon is the parent Cca horizon (also zone of $CaCO_3$ accumulation). Due to the fine texture, the soil has limitations for disposal of sewage effluent and construction of roads and buildings. Construction here is quite feasible but will require extra expense to overcome severe shrink-swell and frost heave potential. Low permeability limits the amount of sewage effluent the soil can receive to nearly the amount it can lose by evapotranspiration.

Al -fs Alluvium, fine sandy

Towards the apex of the alluvial fan at the mouth of Red Creek, the creek had a steeper gradient and could carry and deposit coarser particles. Therefore, to the north, the fan material becomes coarser, grading from a loam or clay loam south of the highway to a fine sandy loam at the hunting camp. The coarser material is more suited for development, being less susceptible to shrink-swell and frost heave hazards. However, excavation and gravel fillings of foundations and road beds would still be required.

Al - c Coarse alluvium

This mapping unit is found on a steep alluvial fan on the south side of Mt. Hebgen. This coarse material presents only slight hazards for development.

COLLUVIAL - ALLUVIAL UNITS

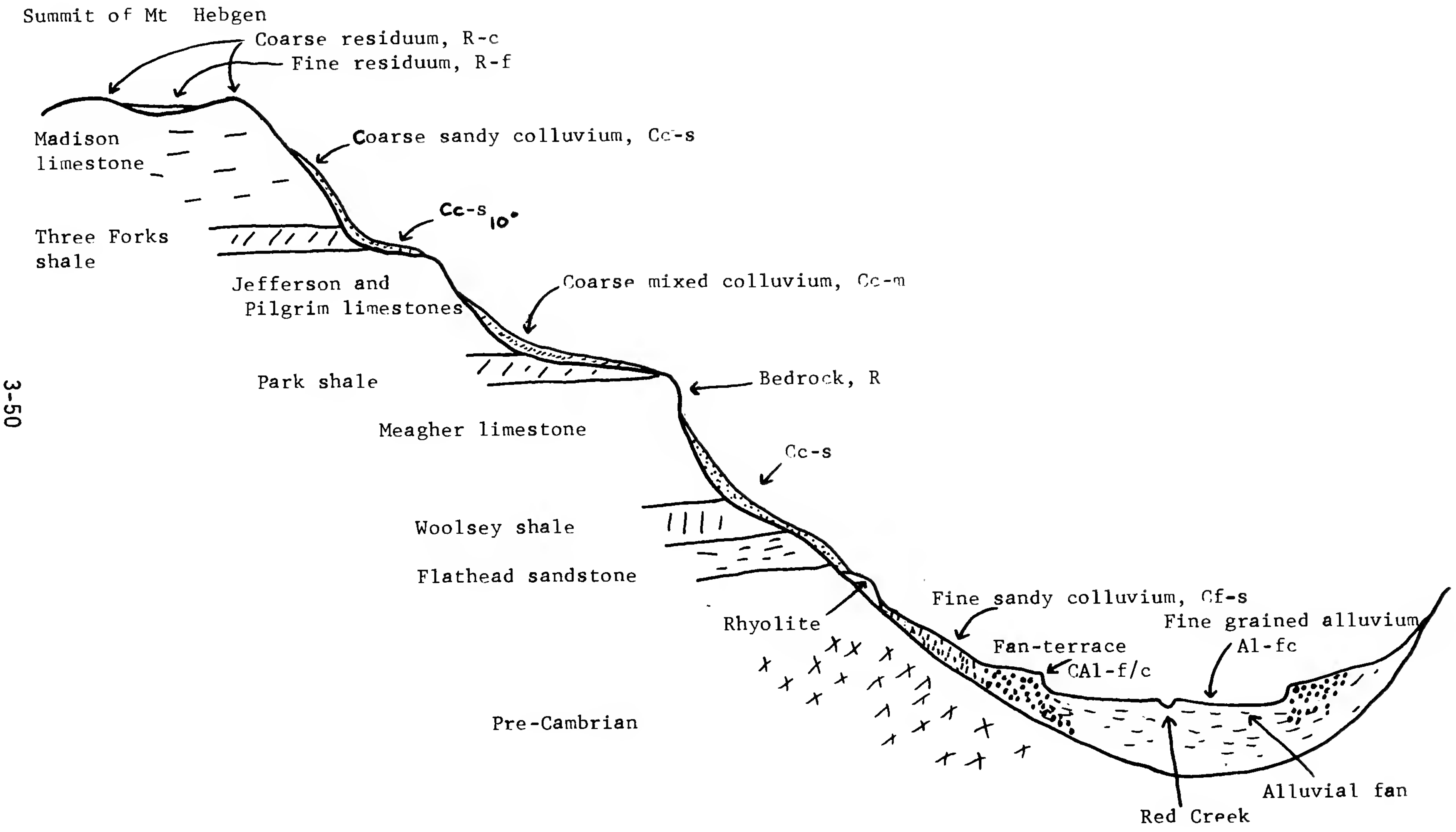
CAl - c Coarse, Co-alluvium (collumium and alluvium mixed)

During periods of increased fluvial activity (glacial), Red Creek built terraces which now exist along both sides of the Pinedale alluvial fan. Since these stream terraces border the mountain flanks, the rounded stream materials have been mixed with angular colluvial materials from the mountain slopes. These features are fan-terraces which combine the features of both terraces and fans. The fan-terraces consist of coarse rock materials with a fine (sandy or clayey) matrix. These soils have weak mollic A horizons, B horizons with some clay accumulation and underlying Cca parent material horizons. Clay present in the matrix of the soil and in the B horizon may present slight limitations for development. Some of the B horizons are especially clayey and excavations for septic tanks, road beds or foundations may have to extend beneath them. The very coarse C horizon is well suited to development activities.

CAl - Flc Co-alluvium, fine over coarse

This units is found where fan-terraces are mantled with fine grained co-alluvial material from the rhyolite, sandstone and Pre-Cambrian hillslopes.

GENERALIZED WEST TO EAST CROSS-SECTION SHOWING LOCATION OF GEOLOGIC UNITS AND SOILS-SURFICIAL GEOLOGY UNITS



The fine grained soil is a dark sandy loam with some construction limitations due to frost heave and shrink-swell potential. It is underlain at moderate (3 feet) depth by a coarse Cca horizon with no construction limitations. The fine grained soil supports a more lush grassland vegetation than does the corase alluvium.

COLLUVIAL DEPOSITS

The flanks of Mt. Hebgen are mantled by colluvial debris derived from the "layer cake" bedrock units of Mt. Hebgen. The colluvial soils-surficial geology deposits can almost be mapped directly from the geologic map. The materials can be divided into the broad categories of fine and coarse. The fine sized deposits are derived from rhyolite, sandstone and Pre-Cambrian rocks. The coarse units have abundant (20-95%) coarse fragements, primarily limestone.

Cc - c Coarse clayey colluvium

This mapping unit is found where fragments of limestone are mixed in a clayey (shale derived) matrix. The clay, when examined alone, possesses severe limitations for development, (instability, shrink-swell, frost heave). The occurrence of coarse fragments (rocks) in the colluvial material significantly lessens the predictable hazard. Potential construction sites in the mapping unit should be evaluated for limitations due to instability, shrink-swell and frost heave potential. The limitations are not serious enough to preclude construction.

Cc - s Coarse sandy colluvium

This unit is the dominant one on the sides of Mt. Hebgen. It is derived primarily from the Cambrian Meagher and Mississippian Madison limestones. The matrix is a sandy loam with a low clay content. Most of this unit is found on steep slopes (30^o) near and below bedrock outcrops. Some of the flatter (10^o) benches on the mountain have been mantled with sandy colluvium. Because of a difference in erosion potential, the flatter (10^o) units of sandy colluvium are mapped separately. The sandy texture and abundant coarse fragments give this unit a very high permeability. Developmental limitations associated with excess water will likely be nonexistent. Due to its low water holding capacity, the south facing slopes in this unit have sparse vegetative cover. The sandy soil is easily eroded if surface water availability exceeds permeability. Therefore, these soils may have a moderate to severe erosion hazard for ski trails cleared on the south and east facing slopes. Mulching should alleviate this potential problem and encourage establishment of erosion resistant vegetation. If clearing is done on these slopes, as much of the understory vegetation as possible should be left intact.

Cc - m Coarse mixed colluvium

This colluvial unit is a mixture of the two previous units. Because there are shales interbedded between and among the colluvial forming limestones, it is often hard to map a unit as being entirely sandy or clayey. Much of this unit occurs in colluvial material developed from the Pilgrim limestone. Clay is derived from the overlying Dry Creek, Maywood and Red Lion Formations and has mixed with fragments of Pilgrim limestone. Some areas mapped in the mixed category pose development limitations because of potential instability and shrink-swell and frost heave potential. Therefore, individual construction projects should be pre-evaluated on site.

FINE COLLUVIUM UNITS

Cf - c Fine clayey colluvium

This unit is found with shales on the face of Mt. Hebgen and often is associated with ground water discharge areas. It possesses severe limitations for construction due to frost heave and shrink-swell potential. If there is sufficient slope, the clayey soil can be unstable. However, this unit is usually associated with the flatter benches of Mt. Hebgen where there is no instability potential.

Cf - s Fine sandy colluvium

The sandy colluvium unit is derived from rhyolite (welded tuff), sandstone and Pre-Cambrian rock outcrops on the lower south and east facing flanks of Mt. Hebgen. These rock materials tend to weather into sand size particles and move a short ways down slope as colluvium. These soils are well drained sandy loams. In many places they have construction limitations due to shallow depth to bedrock. Generally, they are the most developable hillslope soils in the mapping area. Due to their high permeability, these soils have only a slight erosion potential if trail clearing takes place. If trails are cleared, their soils should be mulched or otherwise protected.

Ls Landslide

There are several areas of landsliding on Mt. Hebgen. The largest is located in S2 and S35 where the present logging road crosses it. This landslide has developed in the Park shale and spread upward to include the Pilgrim limestone. It has been mapped in two sections, active and inactive. The inactive (major) portion shows no sign of movement during historic times. The active core may be subject to mass movement at any time. Construction is possible on the inactive slide if absolutely necessary. If construction occurs, clay areas should be avoided and wet areas drained. The smaller active portion comprises the center of the inactive landslide. It has abundant shale and clay on the surface associated with both standing and running water. This slide should be avoided by all construction activities. If a major road is built in the present road location, it will cross this hazard area. It may

be best to cross it at the lower portion near the outcrops of Meagher limestone. In this location it might be possible to bridge the wet shaly portion of the slide by using outcrops of Meagher limestone on either side of the small landslide canyon.

RESIDUAL UNITS

Due to the flat geological structure of the Madison limestone, the top of Mt. Hebgen is an area of gentle relief where extensive stream and slope erosion has not taken place. This area has been mapped in two soil-surficial geology units, a fine material unit and a coarse material unit.

R - f Fine grained residuum

Fine grained residuum is found in the swales on top of the mountain. A soil pit revealed very clayey material underlain at a depth of five feet by very fine sand. The clay material has extreme limitations for development because of high frost heave and shrink-swell potential. Construction activities here should be prefaced by removal of the fine grained material and laying of a gravel sub-base. Low permeability makes the clayey material unsuitable for septic tank drainfield use. A drainfield might work in the sandy layer beneath.

R - c Coarse residuum

The higher land above the swales consists of a coarse mixture of limestone fragments, limestone outcrop and fine grained soil. Geologically it is a mixture of bedrock and frost rubble. This land may be good for construction if the shallow depth to bedrock is not a limiting factor. Each construction site should be examined to determine its susceptibility to frost heave. Jointing in the limestone has given this unit very great permeability and therefore frost heave problems should be minimal. The unit should not be used for effluent disposal unless test drilling and other test procedures prove otherwise.

R Bedrock outcrop

Significant exposures of bedrock outcrop have been mapped. Many of these occur in the Meagher limestone midway up Mt. Hebgen. Many small rock outcrops were either undetected by field investigation or photo interpretation or were too small to be separately mapped.

DISCUSSION

PRESENT USES AND IMPACTS

From the soils-surficial geology standpoint, man has not yet made a major impact on the Mt. Hebgen-Red Canyon area. The major road up the mountain

and resultant timbering on the landslide in S2 and S35 may have reactivated a small portion of it. The slide as it exists now is not a major limitation to the area's environmental quality. The road and the three other clearcut blocks are minor sources of sediment pollution for Red Creek. Their contribution is probably small enough to be barely measurable. Other current uses of the area, hay raising and cattle grazing, do not appear to be significantly altering the environmental quality from the soils standpoint.

FUTURE USES AND IMPACTS

The writer believes that the proposed Ski Yellowstone development will not have a significant effect on the soils resource of the area. The adherence to simple guidelines during planning, construction, and ultimate use can minimize short term impacts and reduce potential long term impacts to tolerable levels. The two major limitations may be slope instability and suitability for sewage effluent treatment. The instability hazard will be nearly non-existent if severe unstable zones are examined jointly by a stability expert and the contruction engineer so that proper precautions can be taken. The problem of effluent disposal is primarily one of engineering the system to fit the hydrologic and soils setting. A more critical examination of the potential septic tank drainfield site on top of Mt. Hebgen may be desirable before permanent snow comes.

The other significant soils-surficial geology limitations deal with frost heave and shrink-swell hazard and potential erosion on ski trail clearings. Frost heave and shrink-swell hazards will be encountered if there is construction on the Red Creek alluvial fan or in certain zones on Mt. Hebgen. Proper engineering in construction planning will reduce this hazard to tolerable levels. The additional cost of using these zones for construction should be assumed during planning.

Potential erosion of cleared ski trails should not be significant. This prediction is based on the estimated high permeability of the dry sandy colluvial soils and the high percentage of understory ground cover observed on the fine grained soil sites. Permeability of the sandy erodable slopes may eliminate most erosion because of lack of water. Vegetative cover on the other sites will reduce and retard erosion there. Where ski trails are cleared, understory vegetation should be left as intact as possible. Steep denuded areas should be reseeded and mulched. Diversion ditches may be required in some cases.

To further minimize impacts of construction and ultimate use, a periodic evaluation of plans and inspection of construction sites and activities should be undertaken by someone knowledgeable in geomorphology, slope stability and soils.

APPENDIX I

SELECTED SOIL PROFILE DESCRIPTIONS

Cf-c Fine clayey alluvium

This profile is typical of the Red Creek alluvial fan that extends across south the highway to Hebgen Lake. The site was a backhoe pit 50 yards south of the highway. It is designated on the Soils-surficial Geology Map as site H-1. The results of sample analyses and use interpretations are found in Appendices II and III.

Soil Profile

A1 0 to 9 inches; very dusky red (2.5 YR 2/2 moist); friable slightly sticky, plastic loam; stong medium granular structure.

B1 9 to 18 inches; reddish brown (2.5 YR 4/4 moist); slightly hard friable, slightly sticky, plastic loam; weak fine granular structure.

B2t 18 to 34 inches; reddish brown (2.5 YR 5/4 moist);hard, firm, sticky and plastic loam; weak, medium prismatic structure.

Cca 34 to 97 + inches; reddish brown (2.5 YR 5/4 moist) soft, very friable, slightly sticky, slightly plastic loam; massive structure; strongly effervescent with many distinct calcite veins; common, medium root pores.

Cf-s Fine sandy colluvium

This profile is typical of the sandier portion of the Red Creek alluvial fan near its apex. The site was an archeological pit in the front yard of the hunting camp. Lab analyses were not done on this site.

Soil Profile

A1 0 to 6 inches; brown (7.5 YR 5/2 dry) to dark brown (7.5 YR 4/2 moist) slightly hard, friable slightly sticky plastic silt loam; granular structure; pH 7.8.

B2t 6 to 10 inches; light reddish brown (5 YR 6/4 dry) to reddish brown (5 YR 5/4 moist), hard, firm, nonsticky, plastic, fine sandy silt loam; weak, medium prismatic structure; pH 7.8.

Cca 10 to 40+ inches; brown (7.5 YR 5/4 moist) slightly hard, friable, slightly sticky, slightly plastic fine sandy loam, stongly effervescent with HCl.

CA1-c Coarse sandy colluvium and alluvium

This soil is found on the fan-terraces where the mountain slopes meet the valley floor. The site of this soil profile is on a fan-terrace east of the hunting camp. It is designated H-6 on the map and in the lab and interpretative tables.

Soil Profile

A1 0 to 6 inches; yellowish brown (10 YR 5/4 dry) to very dark grayish brown (10 YR 3/2 moist) slightly hard, friable, nonsticky, slightly plastic silt loam; fine moderate granular structure; pH 7, 10% angular coarse fragments of limestone.

B1 (or B2t?) 6 to 13 inches; yellowish brown (10 YR 5/4 dry) to dark yellowish brown (10 YR 3/4 moist); hard, firm, nonsticky plastic loam; weak coarse prismatic structures; pH 7.5.

B3 13 to 27 inches; light yellowish brown (10 YR 6/4 dry) to pale brown (10 YR 6/3 moist) structure; hard, friable, sticky, plastic clay loam; weak coarse prismatic structure; pH 7.5.

Cca 27 to 50+ inches; sandy gravel, 90% coarse fragments.

CF-s Fine sandy colluvium

This soil profile has developed from rhyolite welded tuff bedrock on a lower flank of Mt. Hebgen. It is located on the map and in the tables as site and sample number H-15.

Soil Profile

A1 0 to 3 inches; pale brown (10 YR 6/3 dry) to dark brown (10 YR 4/3 moist); slightly hard, non sticky, nonplastic sandy loam; moderate fine granular structure; pH 6.5; 20% coarse fragments.

A-C 3 to 18 inches; light yellowish brown (10 YR 6/4 dry) to dark brown (10 YR 4/3 moist); very hard, firm, slightly sticky, nonplastic sandy loam, structureless, 20% coarse fragments, pH 6.8.

C 18 to 35 inches; same as A-C horizon but slightly lighter in color due to nearness to parent bedrock; pH 7.5; 40% coarse fragments of tuff.

R 35 + inches; bedrock.

CA1-f/c Fine over coarse alluvium and colluvium

This site is on a fan-terrace on the southeast flank of Mt. Hebgen. The map location and sample number is H-7.

Soil Profile

A1 0 to 5 inches; dark grayish brown (10 YR 4/2 dry) to very dark grayish brown (10 YR 3/2 moist); slightly hard, friable, nonsticky, slightly plastic sandy loam; moderate medium granular structure; pH 6.5; 10% angular coarse fragments (Pre-Cambrian gneiss).

B2 5 to 19 inches; brown (10 YR 4/3 dry) to very dark grayish brown (10 YR 3/2 moist); hard, friable, nonsticky, nonplastic sandy loam; pH 7; 10% coarse fragments.

C 19 to 35 inches; yellowish brown (10 YR 5/4 moist); friable, nonplastic, nonsticky sandy loam; pH 7, 10% coarse fragments.

IICca 35 to 50 + inches; reddish yellow (5 YR 6/6 moist); loamy gravel; 80% coarse fragments, pH 8, $CaCO_3$ accumulation.

APPENDIX II

Significant Engineering Properties of Selected Mapping Units

Unit	Description	Location	Sample	Horizon	Mech. Anal.	USDA Class.	Unified Class.
Al-fc	Clayey alluvial fan	South of highway in S11	H-1	A_1	50-34-16	loam	ML-CL
				B_1	50-36-14	loam	ML-CL
				Bat	40-34-26	loam	CL
				Cca	40-44-16	loam	CL
Al-Fs	Sandy alluvial fan	North of Grayling at elevation 6025 ft.	H-8	B	52-36-12	loam	ML-CL
				Cca	38-40-22	loam	CL
CAl-c	Coarse co-alluvium fan-terrace	East of hunting camp at elevation 6850 ft.	H-6	A	58-38-4	gravelly sandy loam	SM
				B	36-46-18	gravelly loam	CL
				Cca	70-22-8	angular cobbly sandy loam	SM
CAl-f/c	Co-alluvium fine over coarse fan terrace	Alluvial terrace SE¼ of SE¼ of S2	H-7	A-C	46-44-10	loam	ML
Cc-c	Colluvium coarse, clayey	On mountain road just above landslide	H-14	A	52-22-26	gravelly sandy clayey loam	CL
Cc-c	Colluvium coarse, clayey	Mountain road below landslide	H-16		32-28-40	gravelly clay loam	CL
Cc-s	Colluvium coarse, sandy	SE¼ of SE¼ of S34	H-10		62-34-4	sandy loam	SM
Cf-c	Colluvium fine, clayey	Middle of S35 1/8 mile west of road	H-18		48-22-30	sandy clay loam	CL
Cf-s	Colluvium fine, sandy	SW¼ of S2 elevation - 6725ft.	H-15		68-24-8	sandy loam	SM
R-f	Residuum, fine	Swale meadow on top of Mt. Hebgen	H-9	0"-18"	46-40-14	loam	ML-CL
				18"-60"	42-40-18	loam	CL
				60"-80"		angular cobbly, sand	SM

Significant Engineering Properties of Selected Mapping Units (cont.)

Unit	Coarse Fragment%	Permeability Estimate	COLE%	Shrink-Swell Potential	Liquid Limit	Plastic Limit	Plasticity Index	Sample	Horizon
A1-fc		Moderate						H-1	A1
		Slow	7.8	High	30%	18%	12		B_1
		Slow	8.2	High	34%	18%	16		B_{2t}
		Slow	9.3	Very High					Cca
A1-Fs		Moderate	3.9	Moderate				H-8	B
		Slow	7.8	High					Cca
CA1-c	33	Moderately Rapid						H-6	A
	75	Moderate	6.0	Moderate	28%	20%	8		B
		Moderately Rapid	2.9	Low	26%	22%	4		Cca
CA1-f/c		Moderate	5.0	Moderate				H-7	A-C
Cc-c	72	Moderate	6.0	High	34%	21%	13	H-14	A
Cc-c	94	Slow						H-16	
Cc-s	67	Very Rapid	5.9	Moderate	25%	21%	4	H-10	
Cf-c	11	Slow	10.2	Very High	36%	23%	13	H-18	
Cf-s	13	Moderately Rapid	1.0	Low	19%	18%	1	H-15	
R-f		Moderately Slow						H-9	0"-18"
		Slow	12.8	Very High	35%	24%	11		18"-60"
		Moderately Rapid							60"-80"

APPENDIX III

Soil Use Ratings Based on Significant Properties

Unit	Sample	Horizon	Shallow Excavations	Dwellings	Roads and Streets	Surface Erosion Pot.	Pot. Frost Action	Septic Tank Absorbtion Field
Al-fc	H-1	A_1	Slight (texture)	Severe (frost, shrink swell)	Moderate (texture) Severe (frost, shrink, swell)	Slight	High	Severe (permeability)
		B_1	Slight (texture)	Moderate (texture)	same as A1		High	Severe (permeability)
		B2t	Slight (texture)	Moderate (texture)	Severe (texture, frost, shrink swell)		High	Severe (permeability)
		Cca	Slight (texture)	Moderate (texture)	same as B2t		High	Severe (permeability)
Al-fs	H-8	B	Slight	Moderate (texture)	Moderate (texture) Severe (frost)	Slight	High	
		Cca	Slight	Severe (frost)	same as H-8 B		High	
CAl-c	H-6	A	Moderate (texture)	Severe (frost)	Severe (frost)	Slight	High	
		B	Moderate (texture)	Moderate (texture)	Moderate (texture) Severe (frost)		High	
		Cca	Moderate (texture)	Severe (stoniness)	Moderate (frost, stoniness)		Moderate	Moderate (permeability)
CAl-f/c	H-7	A-C	Slight (texture)	Moderate (shrink-swell, texture, frost)	Moderate (texture) Severe (frost)	Slight	High	
Cc-c	H-14	A	Severe (stoniness)	Moderate (texture, shrink-swell)		Slight	Moderate	
Cc-c	H-16		Severe (stoniness)	Severe (stoniness) Moderate (texture)		Slight	High	

Soil Use Ratings Based on Significant Properties (cont.)

Unit	Sample	Horizon	Shallow Excavations	Dwellings	Roads and Streets	Surface Erosion Pot.	Pot. Frost Action	Septic Tank Absorbtion Field
Cc-s	H-10		Severe (stoniness, rockiness, depth to bedrock)	Severe (stoniness rockiness)		Moderate	Moderate	
Cf-c	H-18		Severe (drainage)	Severe (drainage)	Moderate (texture) Severe (frost)	Moderate	High	
Cf-s	H-15		Moderate (depth to bedrock)	Moderate (depth to bedrock)		Slight	Moderate	
R-f	H-9	0"-18"	Moderate (texture)	Moderate (texture) Severe (frost)	Moderate (texture) Severe (frost)	Moderate	High	Severe (permeability)
		18"-60"	same as 0"-18"	same as 0-18"	same as 0"-18"		High	
		60"-30"	Slight	Moderate (frost)	Moderate (frost)			

These interpretations are based on tables found in Guidebook for Soil Survey, 1972 Work Planning Conference, U. S. Dept. Agriculture, Soil Conservation Service, Portland, Oregon.

GLOSSARY OF SELECTED TERMS

A1	Soil mineral horizons of organic - matter accumulation formed or forming at or adjacent to the surface.
Alluvium	A general term for all detrital deposits resulting from the operations of modern rivers.
Alluvial Fan	A cone shaped deposit of alluvium made by a stream where it runs out onto a level plain.
Bt	Soil horizon in which clay has accumulated.
Cca	Soil horizon of parent material which has accumulation of calcium carbonate.
Co-Alluvium	Term describing depositional mixtures of alluvium and colluvium. This term has been derived for the purposes of this report and is not in general usage.
Colluvium	A deposit of rock fragments and soil material accumulated at the base of steep slopes as a result of gravitational action.
Epipedon	The uppermost soil horizon.
Loam	Soil material that contains 7 to 27% clay, 28 to 50% silt and less than 52% sand.
Mollic	A surface soil horizon that is dark and rich in bases; usually developed under grass.
Pinedale	The most recent major stage of the Wisconsin Glaciation, as it is known in the Yellowstone Park - Hebgen Lake area.
Quaternary	A geologic period including geologic time and deposits from the end of the Tertiary up to and including the present.
Residual Material or Residuum	Unconsolidated and partly weathered mineral materials accumulated by disintegration of consolidated rock in place.

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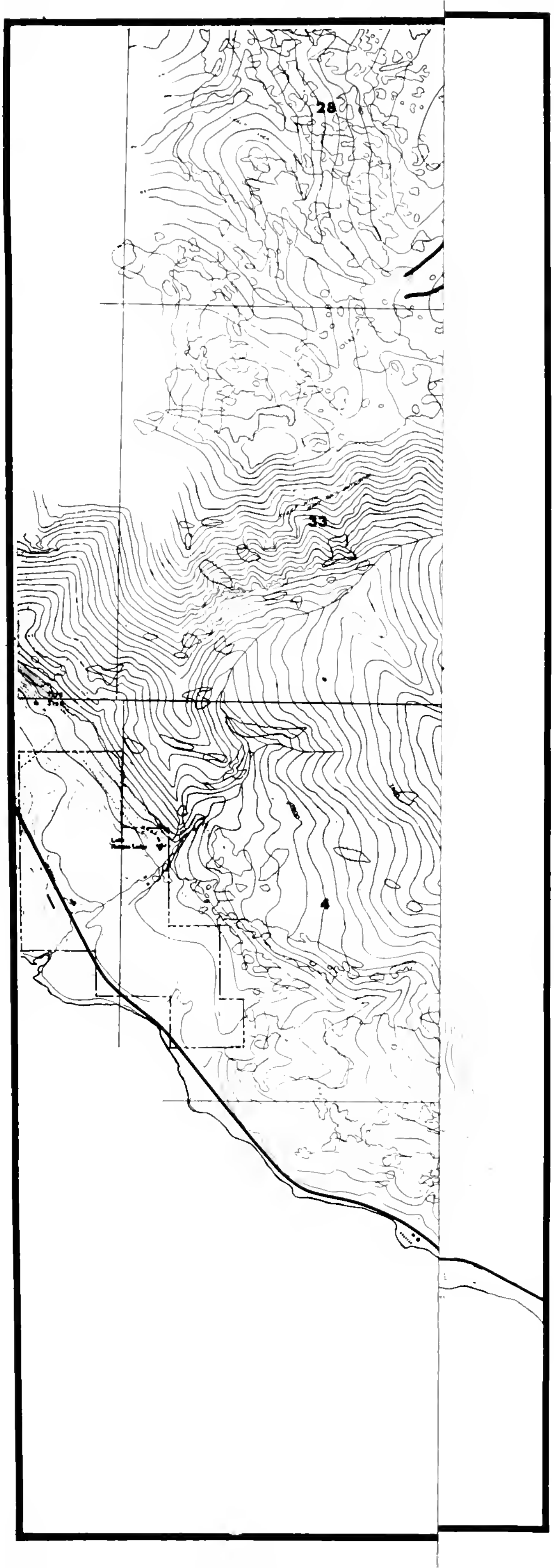


ENVIRONMENTAL SUMMARY

PRIMARY STUDY AREA

SOILS · SURFICIAL GEOLOGY INVENTORY

BY CLIFFORD MONTAGNE

SYMBOL	UNIT NAME
Al·c	COARSE ALLUVIUM
Al·fs	FINE SANDY ALLUVIUM
Al·fc	FINE CLAYEY ALLUVIUM
CAl·c	CO·ALLUVIUM, COARSE
CAl·f/c	CO·ALLUVIUM, FINE OVER COARSE
Cc·c	COARSE COLLUVIUM, CLAYEY
Cc·s(·10', where on gentle slope)	COARSE COLLUVIUM, SANDY
Cc·m	COARSE COLLUVIUM, MIXED
Cf·c	FINE COLLUVIUM, CLAYEY
Cf·s	FINE COLLUVIUM, SANDY
Cf·m	FINE COLLUVIUM, MIXED
Ls	LANDSLIDE
R·f	RESIDUUM, FINE
R·c	RESIDUUM, COARSE

MAPPING UNIT BOUNDARY

DIRECTION OF SLOPE MASS MOVEMENT

? QUESTIONABLE OR DIFFUSE BOUNDARY

ACTIVE MASS MOVEMENT CRACK

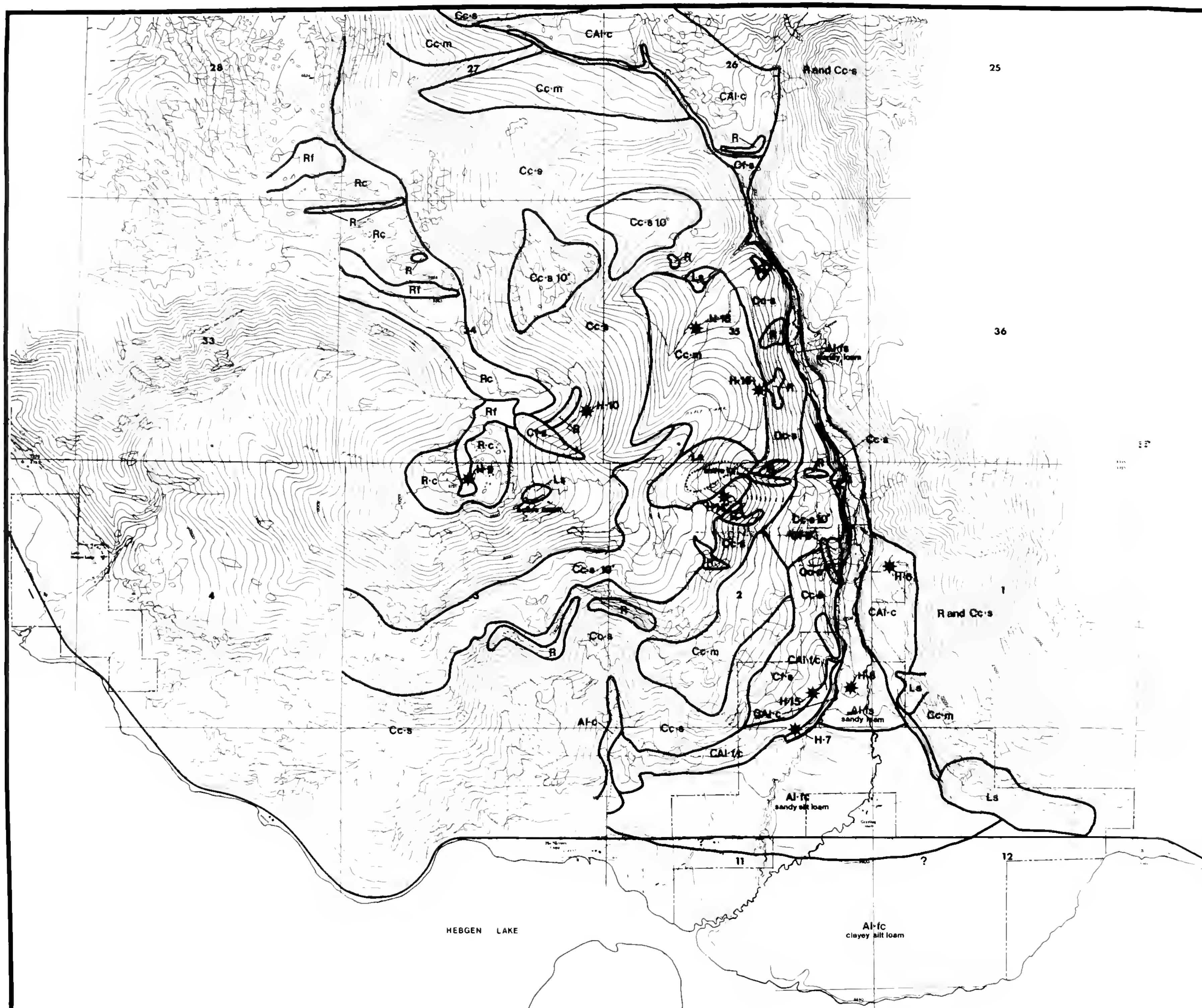
SAMPLE LOCATION & NUMBER

SKI YELLOWSTONE

SKI YELLOWSTONE INC.

WEST YELLOWSTONE, MONTANA

SCALE 1"- 2000'



ENVIRONMENTAL SUMMARY

PRIMARY STUDY AREA

SOILS · SURFICIAL GEOLOGY INVENTORY

BY CLIFFORD MONTAGNE

SYMBOL	UNIT NAME
Al·c	COARSE ALLUVIUM
Al·fs	FINE SANDY ALLUVIUM
Al·fc	FINE CLAYEY ALLUVIUM
CAl·c	CO ALLUVIUM, COARSE
CAl f/c	CO ALLUVIUM, FINE OVER COARSE
Cc·c	COARSE COLLUVIUM, CLAYEY
Cc·s (10° where on gentle slope)	COARSE COLLUVIUM, SANDY
Cc·m	COARSE COLLUVIUM, MIXED
Cf·c	FINE COLLUVIUM, CLAYEY
Cf·s	FINE COLLUVIUM, SANDY
Cf·m	FINE COLLUVIUM, MIXED
Ls	LANDSLIDE
R·f	RESIDUUM, FINE
R·c	RESIDUUM, COARSE

MAPPING UNIT BOUNDARY

DIRECTION OF SLOPE MASS MOVEMENT

? QUESTIONABLE OR DIFFUSE BOUNDARY

ACTIVE MASS MOVEMENT CRACK

SAMPLE LOCATION & NUMBER

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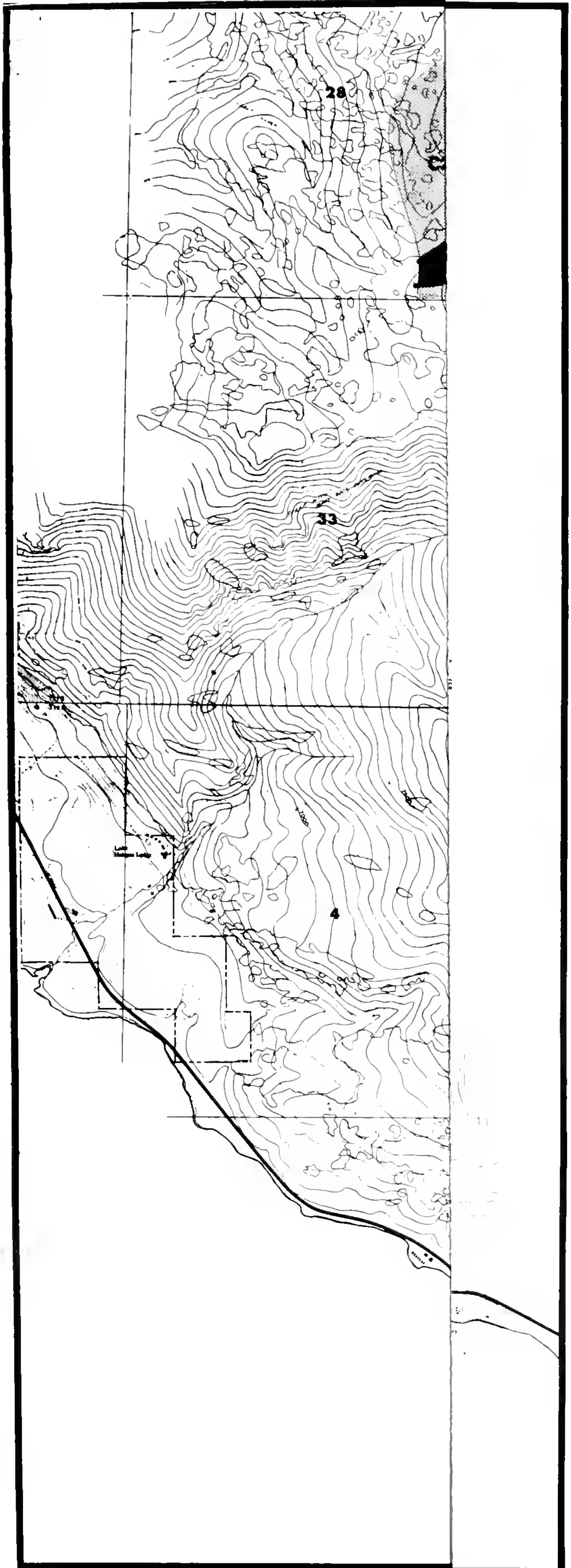
WEST YELLOWSTONE, MONTANA

SCALE 1" = 2000'



ENVIRONMENTAL SUMMARY

PRIMARY STUDY AREA

SOILS· SURFICIAL GEOLOGY DEVELOPMENT LIMITATION ZONES

BY CLIFFORD MONTAGNE

LIMITATION TYPES.....

- A1 — LIMITATION FOR CONSTRUCTION: ACTIVE LAND-SLIDE OR HIGH POTENTIAL FOR MASS MOVEMENT
- A2 — LIMITATION FOR SEPTIC TANK DRAINFIELD: LOW PERMEABILITY
- B1 — LIMITATION FOR CONSTRUCTION: INACTIVE LANDSLIDES
- B2 — LIMITATION FOR CONSTRUCTION: WET CLAYEY SOIL ON STEEP SLOPES
- B3 — LIMITATION FOR CONSTRUCTION: HIGH SHRINK SWELL AND FROST HEAVE POTENTIAL
- C1 — ROAD CONSTRUCTION & SKI TRAIL CLEARING IMPACT: SOIL EROSION ON STEEP SOUTH FACING SANDY PREVIOUSLY VEGETATED SLOPES
- C2 — LIMITATION FOR CONSTRUCTION: SHALLOW DEPTH TO BEDROCK

DEGREE OF LIMITATION/IMPACT.....

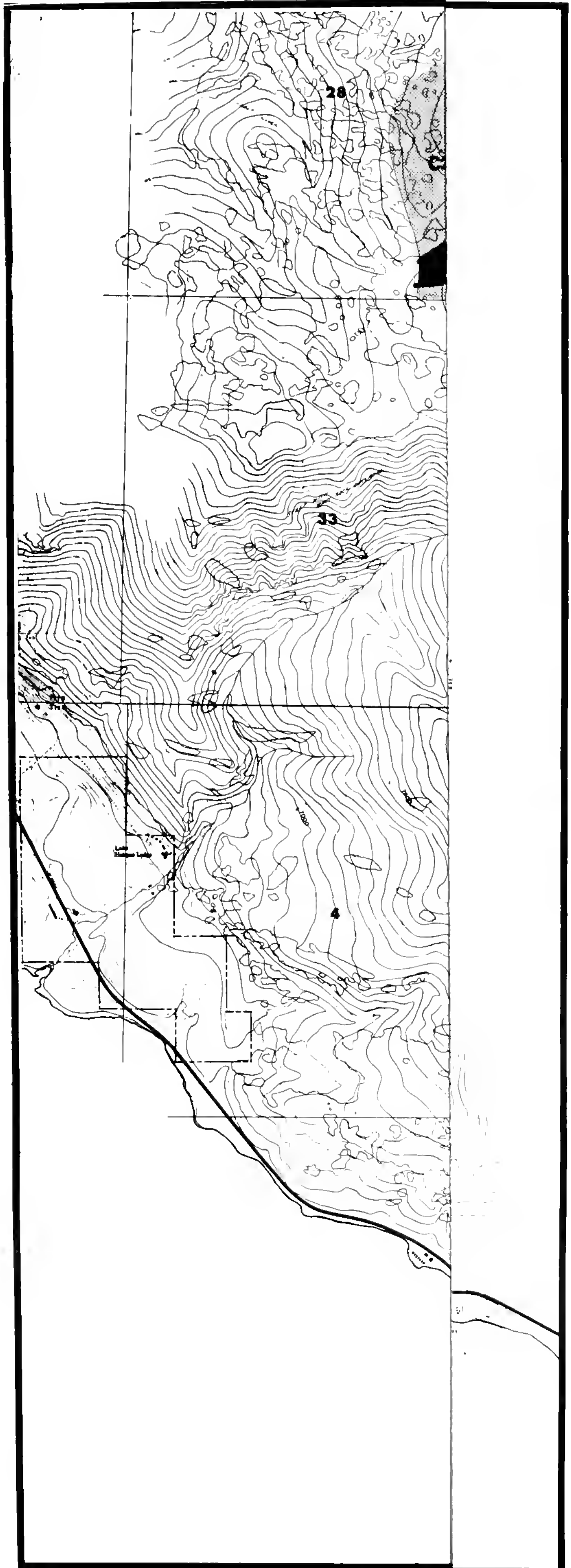
- SEVERE LIMITATION
- MODERATE LIMITATION
- SHORT-TERM MODERATE IMPACT OR LIMITATION

SKI YELLOWSTONE

SKI YELLOWSTONE INC.

WEST YELLOWSTONE, MONTANA

SCALE 1" 2000'



ENVIRONMENTAL SUMMARY

PRIMARY STUDY AREA

SOILS · SURFICIAL GEOLOGY DEVELOPMENT LIMITATION ZONES

BY CLIFFORD MONTAGNE

LIMITATION TYPES.....

- A1 LIMITATION FOR CONSTRUCTION: ACTIVE LANDSLIDE OR HIGH POTENTIAL FOR MASS MOVEMENT
- A2 LIMITATION FOR SEPTIC TANK DRAINFIELD: LOW PERMEABILITY
- B1 LIMITATION FOR CONSTRUCTION: INACTIVE LANDSLIDES
- B2 LIMITATION FOR CONSTRUCTION: WET CLAYEY SOIL ON STEEP SLOPES
- B3 LIMITATION FOR CONSTRUCTION: HIGH SHRINK SWELL AND FROST HEAVE POTENTIAL
- C1 ROAD CONSTRUCTION & SKI TRAIL CLEARING IMPACT: SOIL EROSION ON STEEP SOUTH FACING SANDY PREVIOUSLY VEGETATED SLOPES
- C2 LIMITATION FOR CONSTRUCTION: SHALLOW DEPTH TO BEDROCK

DEGREE OF LIMITATION/IMPACT.....

- SEVERE LIMITATION
- MODERATE LIMITATION
- SHORT-TERM MODERATE IMPACT OR LIMITATION

SKI YELLOWSTONE

SKI YELLOWSTONE INC.

WEST YELLOWSTONE, MONTANA

SCALE 1" 2000'

ENVIRONMENTAL SUMMARY

PRIMARY STUDY AREA

SOILS · SURFICIAL GEOLOGY DEVELOPMENT LIMITATION ZONES

BY CLIFFORD MONTAGNE

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- C2 — LIMITATION FOR CONSTRUCTION: SHALLOW DEPTH TO BEDROCK

DEGREE OF LIMITATION / IMPACT.....

- SEVERE LIMITATION
- MODERATE LIMITATION
- SHORT TERM MODERATE IMPACT OR LIMITATION

SKI YELLOWSTONE

SKI YELLOWSTONE INC.

WEST YELLOWSTONE, MONTANA

SCALE 1" 2000'

EVALUATION OF HYDROLOGIC CHARACTERISTICS

Donald Alford

GENERAL STATEMENT

There are a variety of alternative approaches which may be used in the preparation of a report such as this. These may be dictated as much by current styles in scientific writing and one's personal definition of an "environment" and an "environmental impact" as by the primary purpose of the report--to communicate the findings of the study of a particular area.

In this paper, I have attempted to steer something of a middle course between what might appear to the interested layman as technical jargon and a bald recitation of the basic elements of the hydrologic cycle of Red Canyon Creek as I interpret it. The report is written in narrative style, with the more salient aspects illustrated in graphical form. I have drawn conclusions as to an "environmental impact" the development of a ski area on the east slopes of Mt. Hebgen will have. I have attempted to write this report in such a way that the interested non-hydrologist may draw his own. It is my opinion that only in this way will an acceptable solution result and perhaps, out of this will come a more complete understanding of some of the complexities which must be considered in dealing with any problem concerning the natural interaction of physical properties and processes in the mountains.

I feel it is useful to make one final point in this section. Each of us must be our own expert in the area of aesthetics and I have purposely attempted to avoid a discussion of these elements of the problem here. This is not meant to imply that the potential for real and lasting impacts does not exist when man begins the development of a region of the earth as fragile as are the mountains. It is the responsibility of the scientist to be aware of the possible forms this type of impact may take and to bring it to the attention of the widest possible audience. It was with this in mind that this study was undertaken and the preparation of this report completed.

EVALUATION OF HYDROLOGIC CHARACTERISTICS

Donald Alford

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INTRODUCTION

It is the purpose of this report to discuss the results of a study of the hydrologic characteristics of Red Canyon Creek in the southern portion of Gallatin County, Montana. This study was conducted by the writer for the Ski Yellowstone Corporation as one aspect of a general environmental analysis. Because of limitations of both time and money, the results obtained during this study and the conclusions drawn upon them can undoubtedly be refined to greater precision by a more intensive program of hydrologic research in the catchment basin. However, it is felt that the conclusions reached here are essentially those which would result from any scale of study in the basin and will differ only in absolute quantitative terms.

It is considered useful at this point to discuss some of the problems faced by a hydrologist working in the field and some of the limitations which are imposed by the techniques available to him and by the various hydrologic "models" which have evolved over the years. Particularly in the context of the present study, it is considered necessary to stress the problems of extrapolating hydrologic "models" from the area of their conception to other environments, particularly that of the mountains.

For any given watershed, which may be defined as a bowl which is breached at one or more points along its lip without regard to surface area, the hydrologic resources consist of <u>inputs</u>, which may be either atmospheric, that is, rain and snow, or which may occur as surface or subsurface flow from a contiguous basin; <u>outputs</u>, which are 1) surface runoff, 2) subsurface outflow, and 3) evapotranspiration; and, <u>storage</u>, or the groundwater reserves of the basin. The spatial and temporal distribution of these resources is determined to some extent by the morphology, that is, the form, of the watershed and by the underlying rock types and their structural interrelationships. Because each of the factors which influence the final hydrologic budget may interact in a completely random manner (here, the "hydrologic budget" is defined as the algebraic summation of all inputs, outputs and storage), it becomes apparent that if any of the controlling factors varies either temporally or spatially, the solution of the hydrologic equation will also vary. The mountains present the scientist with perhaps the most variable environment on the surface of the earth and consequently, a solution may have little application if it is extrapolated through either space or time. One is thus forced to consider the hydrology of any mountain watershed as a problem in stochastics, that is, as one involving the random interaction of a series of random variables and there are thus no "absolute" solutions but rather a series of probabilistic approximations which may be considered to represent the means and extremes of the area under consideration. In terms of this study, therefore, at any given moment and at any given point in the Red Canyon Creek watershed, the water resources may vary widely but should always remain within the limits which this study was undertaken to define.

FIGURE 1

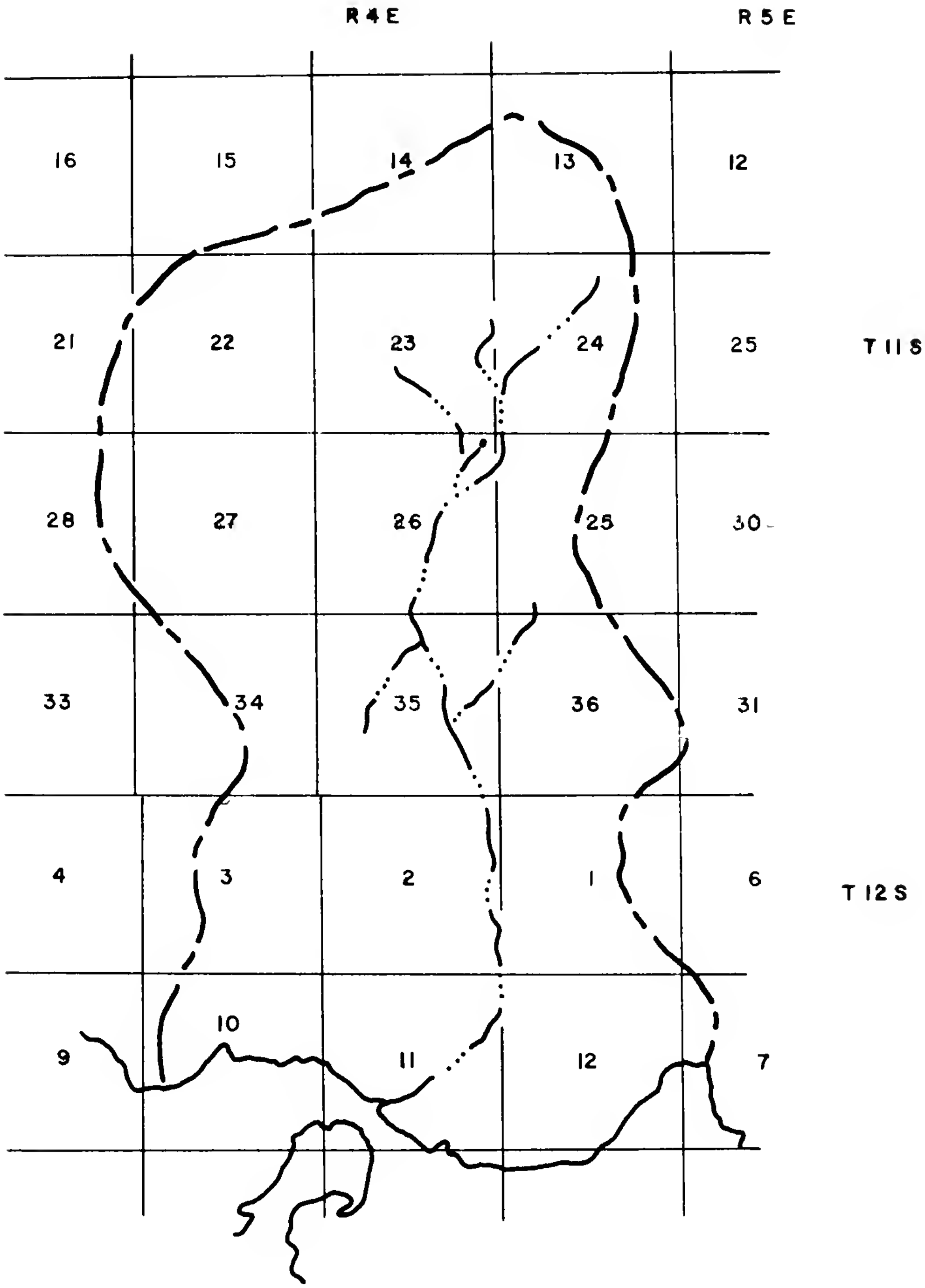


Figure 1. The Red Canyon Creek watershed (heavy broken line) showing its relationship to the Montana Principal Meridian. The location of the presumed perennial streams in the basin is indicated by a lighter broken line.

GEOGRAPHIC LOCATION AND DESCRIPTION

Summary: The Red Canyon Creek watershed lies in the southern portion of Gallatin County, in portions of R4E, T11S and T12S. It has a total surface area of approximately 16 mi^2, elevations ranging from 6550 to over 9600 feet a.s.l. and is drained by Red Canyon Creek, a tributary to Hebgen Lake. The primary orientation of the watershed is to the south. The mean elevation of the basin is between 7800-8000' a.s.l.

The main channel of Red Canyon Creek is slightly more than four miles in length and has an essentially exponential gradient ranging from over 1000'/mile at its head to less than 100'/mile at the point of entry into the Lake. The lower third of the stream flows over a prominent alluvial fan, into which it is incised to depths up to fifteen feet. At least four abandoned master channels are present on the alluvial fan. These have been interpreted as a result of sudden shifts in channel location in the past.

The Red Canyon Creek (also referred to in the literature as "Red Creek") watershed lies on the north shore of Hebgen Lake in the southern portion of Gallatin County, Montana. It is located in all or portions of Sections 13, 14, 15, 22, 23, 24, 25, 26, 27, 28, 34, 35, 36 of R4E, T11S, and Sections 1, 2, 3, 10, 11, and 12, of R4E, T12S (Figure 1). It is bounded on the east by the Tepee Creek drainage which flows into the Gallatin River, on the north and west by the Cabin Creek, Kirkwood Creek and Dave Johnson Creek drainages, all of which are tributary to the Madison River, and, with the exception of a few private holdings, including those of Ski Yellowstone Corporation, is completely within the Gallatin National Forest. The elevation range in the Red Canyon Creek basin is from approximately 6550 feet a.s.l. (the mean elevation of the surface of Hebgen Lake) to slightly in excess of 9600 feet a.s.l. in the northwestern corner on Kirkwood Ridge. The watershed itself is elongate, with a long axis of approximately five miles oriented almost north-south while the short axis, at right angles to this, is approximately two miles in length at its widest point. Figure 2 shows the generalized morphology of the basin and the location of the surface drainage pattern which is presumed to be perennial. The total surface area of the watershed is approximately 16.0 mi^2 and the boundary of this area is indicated in Figures 1 and 2 by a heavy broken line. The effective surface area of the watershed, that portion of the basin which can be considered to contribute inputs to the upper portion of the alluvial fan at the site of the projected Core Village, is approximately 10 mi^2.

The total catchment basin has been divided into eight sub-basins and the alluvial fan (Figure 3). Of the eight sub-basins, only three (marked 1, 3, and 5 in Figure 3 and crosshatched) have perennial surface outflows. Red Canyon Creek originates in sub-basin #1, Coal Creek, a tributary to Red Canyon Creek originates near the ridge crest in sub-basin #5 and an unnamed creek, fed by a series of springs at the base of the Paleozoic limestone of Mt. Hebgen flows into Red Canyon Creek slightly above (north) of the point of entry of Coal Creek.

FIGURE 2

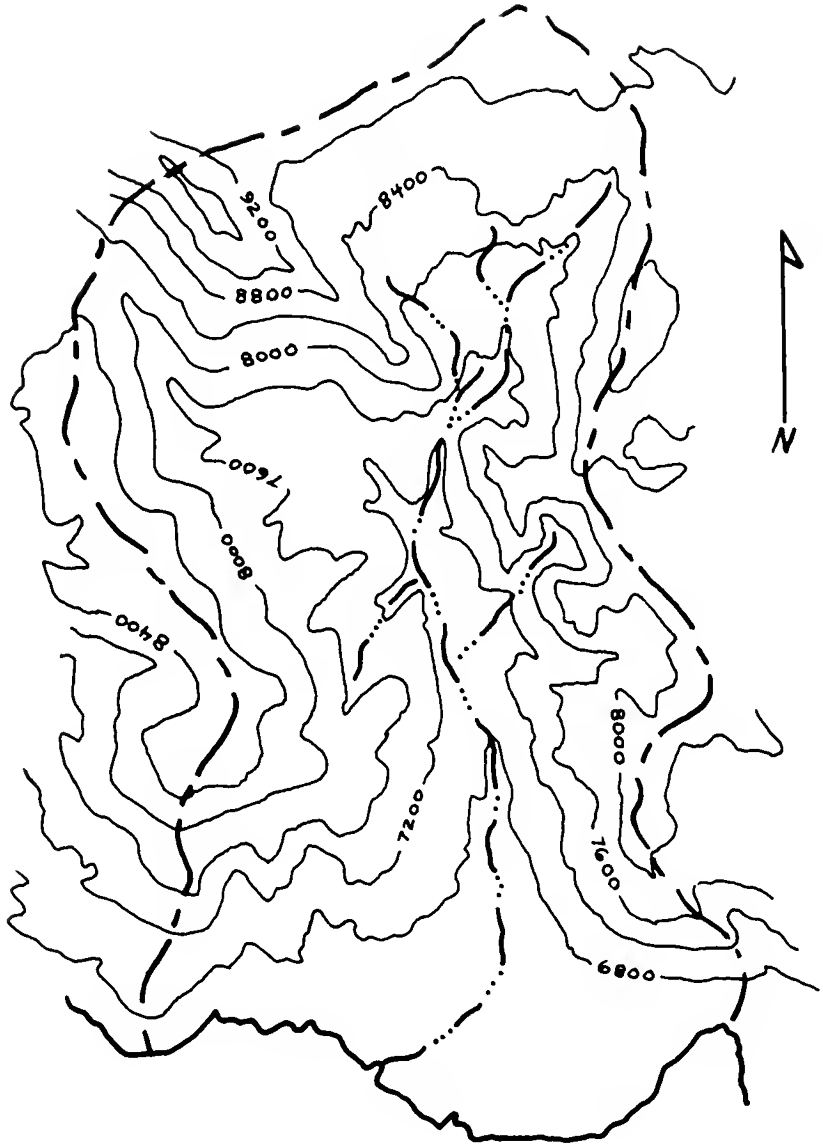


Figure 2. A sketch map, showing the topography of the watershed and its relation to the surface drainage pattern.

FIGURE 3

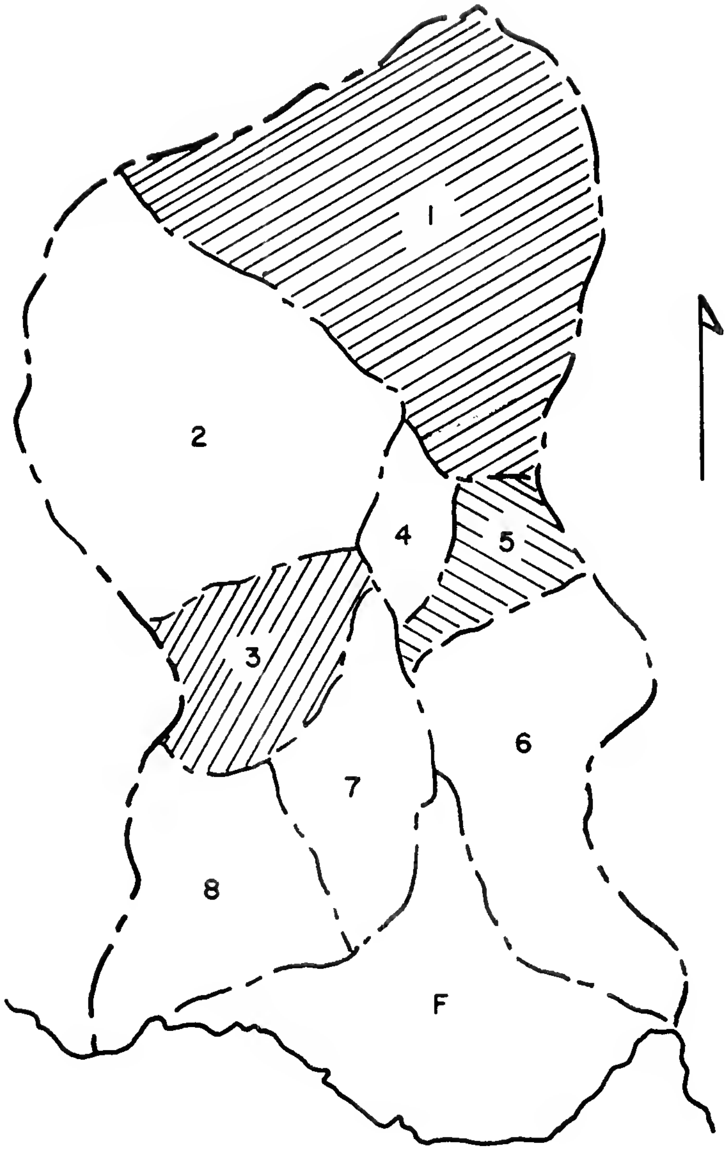


Figure 3. The sub-basins into which the entire watershed of Red Canyon Creek may be divided. (1-8 are the sub-basins, F is the alluvial fan) Numbers 1, 3, and 5, which are cross-hatched, are the sub-basins which produce surface runoff.

FIGURE 4

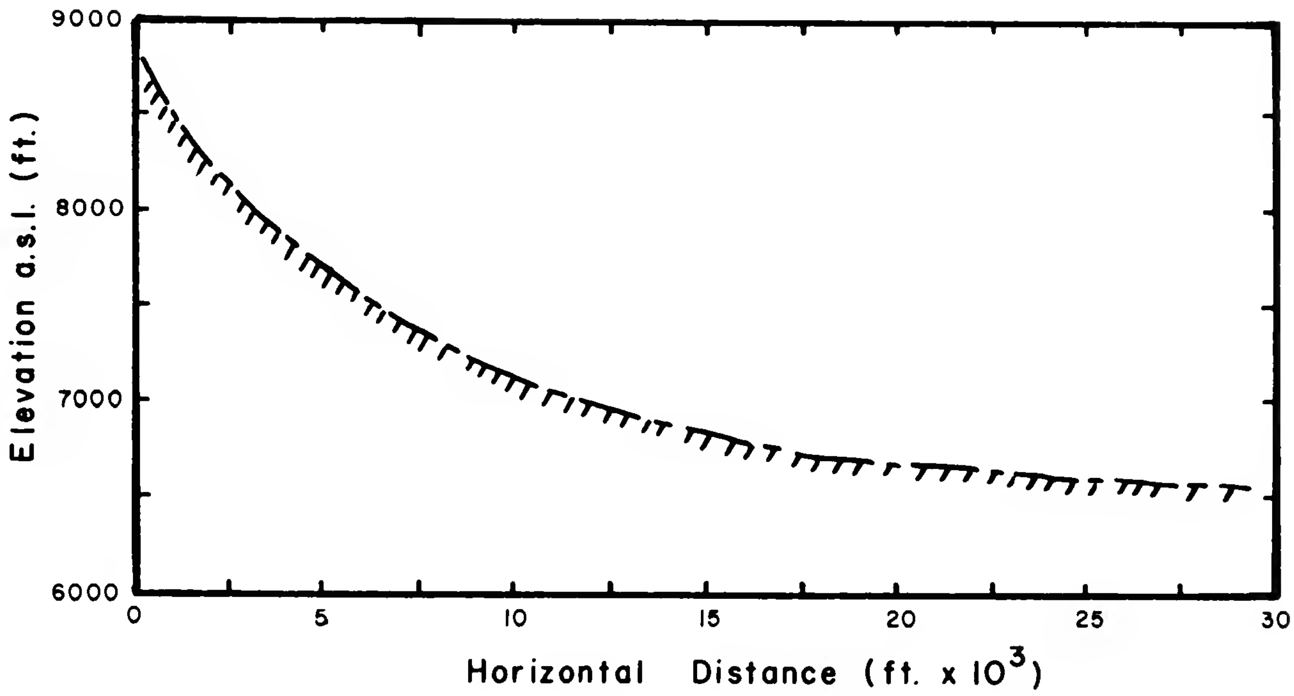
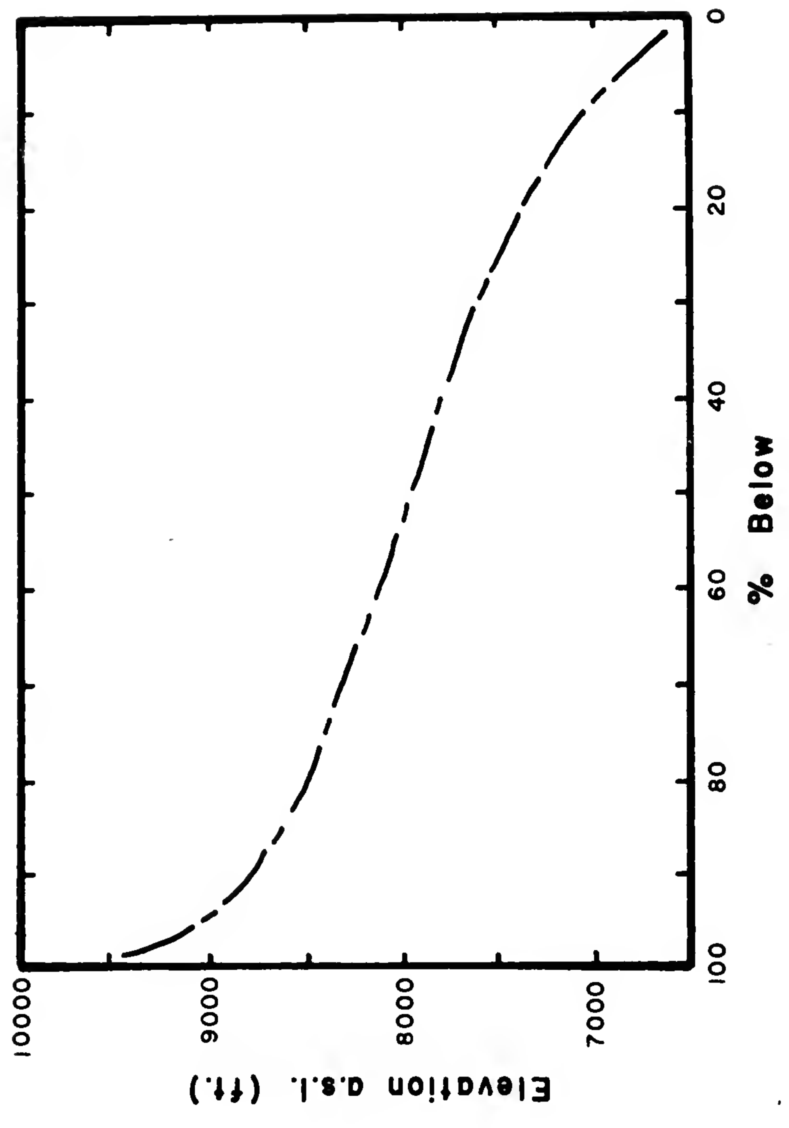


Figure 4. The long profile of Red Canyon Creek from the point of origin in sub-basin #1 (Figure 3) to its entry into Hebgen Lake. Note that the slope angle is a continuous variable of distance from the point of origin.

FIGURE 5



A hypsometric curve of the Red Canyon watershed, showing the relative percentage of the total surface area within any given elevational interval. A majority of the surface area can be seen to lie between roughly 7500 feet and 8500 feet above sea level.

For the purposes of this report, I intend to call this unnamed creek "Spring Creek" simply to facilitate reference to it. The total surface area of the three sub-basins which produce perennial surface runoff is approximately 5.00 mi^2 (Note: all values of surface area were obtained by planimetry of the best available maps of the basin and are rounded off to the nearest whole square mile for ease of computation).

The master channel of Red Canyon Creek originates in Section 26, R4E, T11S at the point of confluence of two second order channels which in turn are the result of four first order channels, two of which drain the west slope of the northern extension of Graycroft Ridge, one of which drains the north slope of Kirkwood Ridge and the last of which originates in a small tarn in Section 26, R4E, T11S. All the first order channels are presumably perennial and spring-fed although the perennial aspect can be determined only by an extended period of observation.

The long profile of the main channel of Red Canyon Creek from the headwaters of the first order channels is shown in Figure 4. An inspection of this Figure will show that the long profile of the stream is essentially a concave, exponential curve with gradients ranging from over 1000'/mile to less than 100'/mile near the shore of Hebgen Lake on the lower alluvial fan. The shape of the long profile curve is characteristic of mountain drainage basins and is indicative of a state of hydraulic quasi-equilibrium.

Because both the volume and timing of runoff from mountain watersheds must be considered as some function of elevation above sea level, a hypsometric curve (Figure 5) has been constructed for the Red Canyon Creek watershed. In effect, this curve shows the percentage of the surface area of the watershed which lies within a given elevational interval. From this Figure, it can be seen that the mean elevation of the basin is between 7800-8000 feet a.s.l. and that approximately 80% of the surface area lies between 7500 feet a.s.l. and 8500 feet a.s.l.

A geographic factor which is critical to an understanding of the hydrologic output of a mountain watershed involves the orientation of slopes within the basin. This parameter will influence precipitation inputs to the system and surface energy transfers, which are of paramount importance in determining the timing of surface runoff from mountain watersheds. The primary problem in developing a slope classification scheme involves the subjective judgment of the investigator as to the scale of the primary meteorological processes which help to determine the hydrologic balance of a basin. In the case of Red Canyon Creek, I have chosen to evaluate the so-called "exposure climate" in terms of assumed meso-scale processes, which ignore the influence of local variations such as gullies, secondary ridge systems and variations in the vegetation pattern. In terms of a meso-scale evaluation of exposure climates, I feel that the Red Canyon Creek watershed can be broken down into six distinct zones which are shown in Figure 6. From this Figure, it can be seen that the exposure of slopes in the basin is conducive to relatively higher rates of surface energy exchange (i.e., there is relatively little surface area oriented toward the northern hemisphere which receives the lowest amounts of incident radiation during the course of the year. Theoretically, south-facing slopes receive the maximum

FIGURE 6

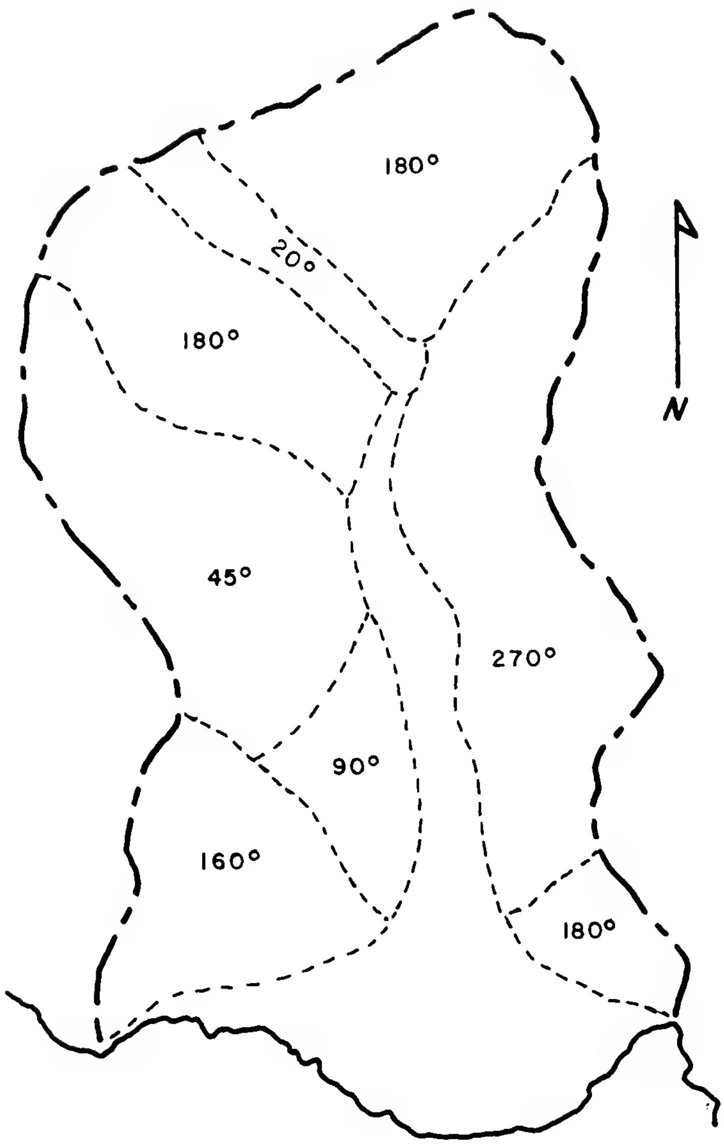


Figure 6. A map showing the general orientation (in terms of true north) of the various slopes forming the walls of the watershed. It can be seen that only a small percentage of the slopes are oriented into the northeastern quadrant and surface energy amounts should thus be relativel high. At the same time, those slopes oriented towards the north-east should receive the highest snowfall amounts due to mesoscale mechanisms controlling snow deposition in the mountains.

possible insolation, east-facing slopes, west-facing slopes and horizontal surfaces receive an intermediate amount and north-facing slopes receive the minimum for the elevation and latitude of the site).

A final geographic factor which deserves some discussion concerns the number of third order channels which are incised into the alluvial fan near and below the proposed site of the Core Village. In addition to the present master channel, there are at least four abandoned master channels located on the alluvial fan in the vicinity of the Core Village site. These include one abandoned channel along the extreme eastern margin of the fan, a second located immediately to the east of the presently occupied channel, a third, the most prominent of the unoccupied channels, is located just west of the occupied channel and a fourth was identified on the extreme western margin of the fan. The initial impression is that the marginal channels are the oldest with those in the center portion of the fan being much younger.

HYDROGEOLOGY

Summary: There are three primary geologic units which influence the ultimate disposition of waters entering the Red Canyon Creek watershed. These are: 1) The Paleozoic limestones, which constitute the primary rock type of the entire western portion of the catchment basin, including Mt. Hebgen. These limestones appear to have very high permeability and it is felt that relatively little surface runoff is produced by that portion of the watershed underlain by these rocks. A number of springs exist in the limestones but, with the exception of those which give rise to "Spring" Creek, the waters are totally influent within a few hundred feet of the point of origin, which is commonly at the contact between the limestone and an interbedded, largely impermeable shale unit. 2) Virtually all of the northeastern corner of the watershed and much of Graycroft Ridge, which forms its eastern boundary, is underlain by Mesozoic sandstones, shales and limestones. It is believed that, because of the lower permeability of these formations, most of the surface runoff from the basin is produced here. In particular, that arising from the spring snowmelt or from heavy rainstorms will originate in this portion of the watershed. The groundwater storage of the Mesozoic rocks will be much less than that of the Paleozoic limestones. Much of the suspended sediments which are transported by Red Canyon Creek are believed to be derived from the Mesozoic sediments. 3) The area in which the Core Village is planned is underlain primarily by Precambrian metasediments over which has been deposited a veneer of Quaternary alluvium and colluvium. The permeability of the Precambrian rocks will be low and they will not constitute a good source of groundwater. The groundwater transmission and storage characteristics of unconsolidated Quaternary sediments should be highly variable, depending largely upon local variations in the clay-sized fraction. In general, this is high at the surface over the lower two-thirds of the alluvial fan. The properties of the alluvium at depth can be determined only by test drilling. Solely from the standpoint of hydrogeology, it is felt that the best source of groundwater will be the Paleozoic limestones which form the lower portion

of Graycroft Ridge along the east side of the canyon.

To the hydrologist, geology represents a fixed set of physical conditions which are invariate with time. They are not, of course, but the relative dynamism of hydrology and geology differ so greatly that the assumption of geologic stability is warranted in most discussions of hydrologic regimes. It is not the purpose of this section to discuss the geologic setting of the Red Canyon Creek areas as that will be done by others in another portion of this report. Here, I would simply like to mention in a cursory fashion, those elements of the geology of the area which I feel are pertinent to an understanding of the transmission of water through the system.

By far the most important rock type in the Red Canyon Creek watershed, in terms of the amount of area which it occupies, is limestone. Limestone, being composed largely of $CaCO_3$, is soluble in acidic solutions, and, while the unaltered rock unit may be completely impermeable, one which has been attacked by acids in the pH range of rainfall may have extremely high porosity and permeability. If this situation is coupled with an extensive fault and/or joint system, as it is in the study area, surface waters may percolate to great depths and produce a series of interconnected cavities which allow the unimpeded flow of a large volume of subsurface waters. For reasons which will be discussed in the section on surface outflows, I believe that a high percentage of the water which leaves the Red Canyon Creek watershed in the liquid form does so as groundwater flow through the limestones forming the floor of much of the basin. It is significant that the primary sub-basin producing surface runoff (#1 in Figure 3) is underlain primarily by rock types other than limestone. On the other hand, sub-basin #2 (Figure 3), which is underlain largely by Mississippian limestones and appears to differ in no other important respect from #1, produces no surface runoff at all. This generalization does not hold for the sub-basins of "Spring" Creek or Coal Creek, both of which have surface drainage and both of which are underlain by extensive areas of limestone. In the case of "Spring" Creek, it appears that the water is being forced to the surface by impermeable zones existing either within or between the limestone beds. These are presumably shale units which are interbedded with the limestones but, in certain cases, may be associated with fault displacements. At any rate, it is probable that all the springs which contribute to the flow of "Spring" Creek and those immediately to the south of its sub-basin are producing outflow which originates on the east slope of Mt. Hebgen. The origin of the waters of Coal Creek, on the other hand, are somewhat more speculative. Coal Creek originates from springs located at about the 8000 foot level on a portion of Graycroft Ridge which is only a few hundred feet higher than this at its crest. Since springs are quite uncommon near mountain summits, it is possible to suggest that the waters of Coal Creek may originate in a sub-basin in the upper portion of the Tepee Creek watershed to the east. While a relatively minor amount of water (estimated at approximately 500 acre-feet/year) is involved in this particular instance, it does raise the possibility of more extensive interbasin subsurface water transfers. If these should, in fact, exist, any rational solution to the hydrologic equation for the Red Canyon Creek watershed, independent of the regional water balance, becomes a virtual impossibility.

A second group of rock units which have some importance in any discussion of the geohydrology of the Red Canyon Creek area are the Pre-Cambrian strata which appear to be the primary rock type beneath the proposed Core Village site. The water transmission characteristics of these units is an unknown factor but it is assumed that their porosity is much lower than is that of the younger limestones in the canyon. Hydrologically, the importance of these strata is associated with their location; I feel that the probability of successfully drilling wells with the production required to support the water needs of the Core Village (estimated by the planners at a maximum of 1000 gpm) is significantly less in the Pre-Cambrian rocks than it is in the limestones. Since the largest surface outcrop of the Pre-Cambrian units is on the west side of the canyon in the vicinity of the proposed Core Village, I feel that any wells drilled in that area should be initially located to the east of the presently occupied master channel of Red Canyon Creek. While the geologic relationships at that point are speculative due to the covering of Quaternary gravels, it appears that the chances of drilling into the limestones of Graycroft Ridge are increased.

From the standpoint of water resources, the third geologic unit in Red Canyon Creek which must be considered is the veneer of unconsolidated Quaternary deposits which mantle much of the floor of the valley. In the primary study area, these range in thickness from a few feet at the "forks" along the southeast margin of Kirkwood Ridge to in excess of 100 feet in the N1/2 of the SE1/4 of Section 11, T12S, R4E (as indicated by a well drilled at that point). Based upon these two data points and reconstruction of long profiles and cross-sections in the vicinity of the Core Village site, it has been concluded that the alluvial fill at that point is of the order of 75-100 feet thick and may reach a maximum in excess of 200 feet near the shore of Hebgen Lake. If this evaluation is correct, it has implications in terms of the source of groundwater which will be available at the Village site. Since the site is over 100 feet (vertical) above the mean Lake level, bedrock will be reached, in drilling, before the water table associated with Hebgen Lake is encountered. While this is not meant to imply that there is no possibility of extracting lake water from a well drilled near the Village site, it is felt that there is much more of a likelihood that the groundwater resources at that location will be derived primarily from upstream inputs to the watershed. Both the presumed volume and timing of these inputs will be discussed below.

No porosity determinations were attempted on the alluvial fill of the valley floor. A series of infiltration tests, intended as a means of crudely assessing permeability rates, indicated that this parameter decreases from unmeasurably high values (in excess of five inches/minute) at various sites above the 7000 foot level along the east face of Hebgen Mountain to approximately two inches/hour in the NE1/4 of the NE1/4 of Section 2, R4E, T12S. These tests were not continued downstream from this latter point as the near surface clay content of the alluvium increased to the point where it was felt that infiltration tests would not necessarily be representative of subsurface conditions. On the basis of these admittedly cursory tests, it is concluded that the permeability of the alluvium in the valley floor is locally high, at least down to the Village site. Extraction of the water necessary for the operation of the Village from the alluvial gravels should be locally possible with no detrimental effect to

FIGURE 7

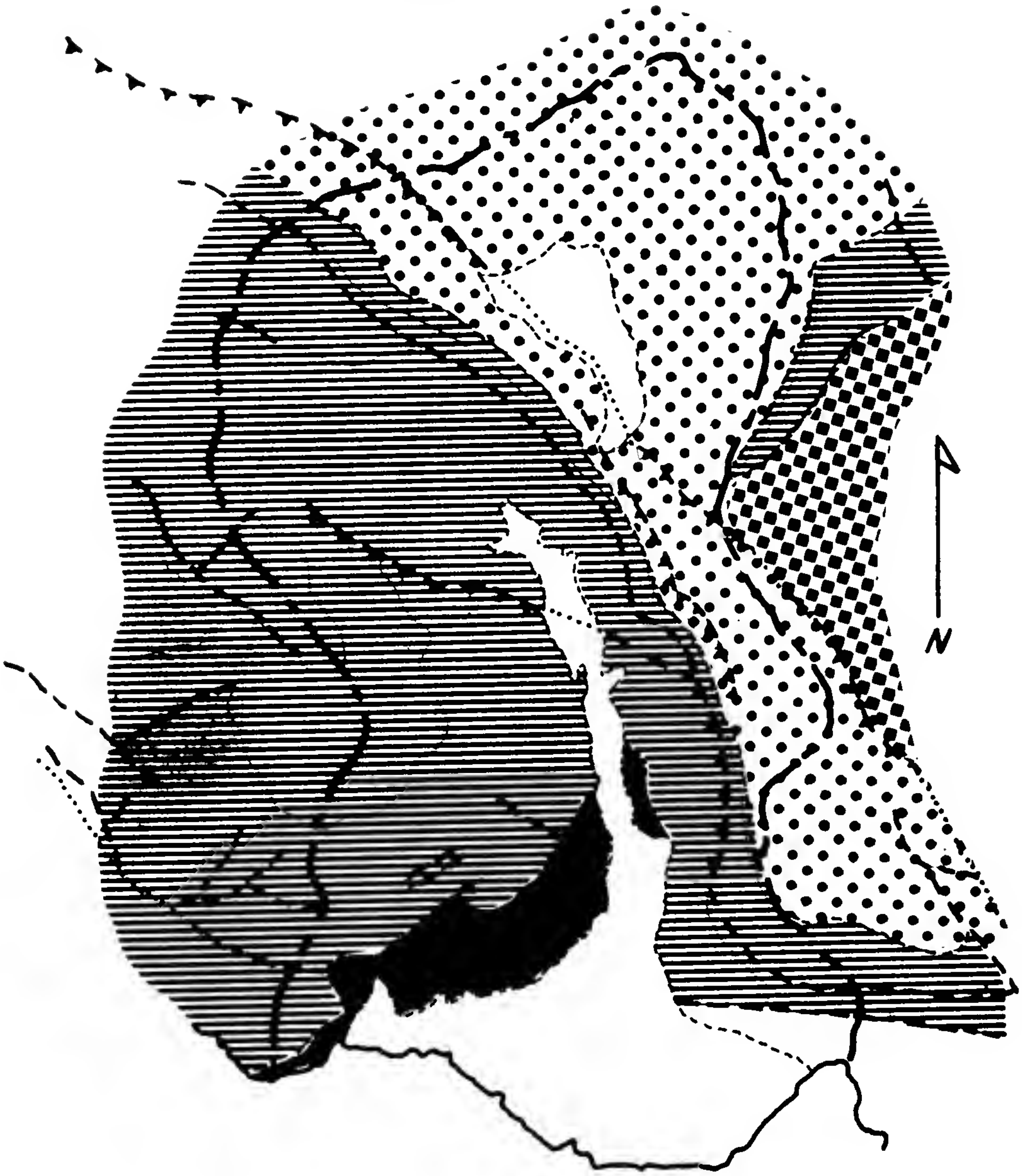


Figure 7. The general hydrogeology of the Red Canyon Creek watershed (Solid: Precambrian metasediments, Lined: Primarily Paleozoic limestones, Closed circles: Mesozoic sediments, White: unconsolidated Quaternary deposits, Closed squares, Tertiary extrusive igneous rocks).

the local water table, assuming that the permeability at depth is similar to that near the surface. The areal pattern of the presumed aquifers is shown in Figure 7.

THE HYDROLOGIC BALANCE OF RED CANYON CREEK

Summary: The hydrologic balance of the Red Canyon Creek watershed has been calculated as the algebraic summation of the measurable sources of water gain, loss and storage.

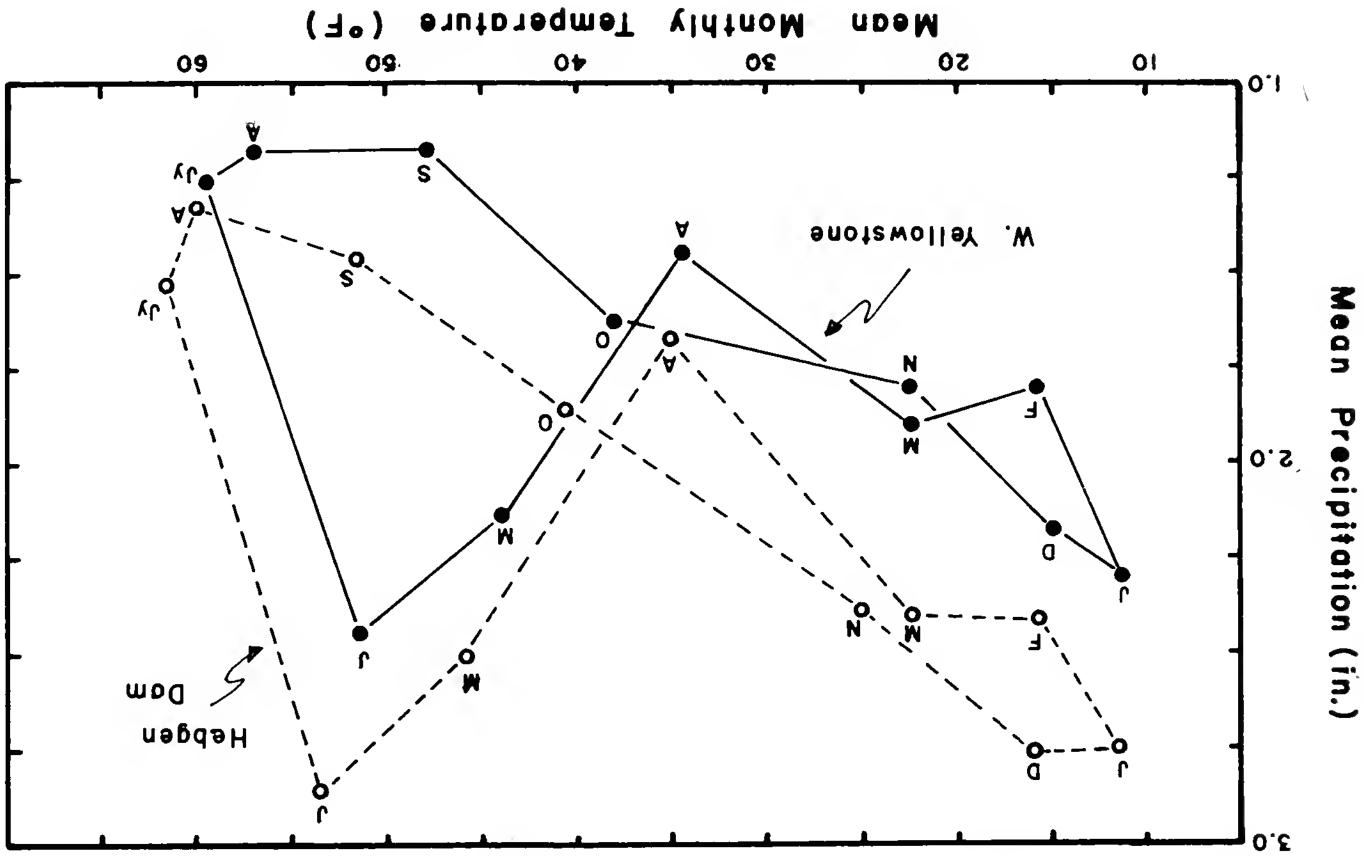
It is believed that the primary source of input to the basin is precipitation, either in the form of rain or snow, which adds an estimated 15,000 - 20,000 acre-feet of water annually. A possible secondary source, subsurface transfers from contiguous watersheds along fault lines and solution channels in the limestones, may add additional water to the groundwater reserves of the Red Canyon Creek basin. Losses include surface runoff which is estimated at 5000 - 7000 acre-feet annually, evapotranspiration, which removes a similar amount and subsurface runoff, which presumably accounts for the remainder.

Based upon the flow characteristics of Red Canyon Creek which were observed during the Spring and early summer of 1973, it is estimated that the mean snowmelt flood of the Creek will be of the order of 100 cfs, the so-called "twenty-five year" flood will be 250 cfs and the maximum flood to be expected should be less than 500 cfs. Flood debris noted along the channel on the lower portion of the alluvial fan suggests that peak flows approaching an order of magnitude greater than this have occurred sometime in the recent past. This may have been a unique event, associated with some non-meteorological event.

The primary spring in the area is Corey Springs, which lies on the extreme eastern edge of the watershed on the shore of Hebgen Lake. The U. S. Geological Survey estimates that the flow of this spring is 7000 gallons per minute. Several smaller springs, producing less than 100 gallons per minute are located along the east slope of Mt. Hebgen. With only one exception, which gives rise to a small tributary to Red Canyon Creek from the west in Section 35, R4E, T11S, the water from these springs is totally influent within a few hundred feet of its point of origin.

In assessing the hydrologic balance of any geographic area, a number of techniques and approaches to the problem have been developed. These range in scope from the measurement of most of the critical variables (i.e., precipitation inputs, surface runoff, changes in groundwater storage) for periods of years to simple spotchecks of surface runoff at intermittent periods. In the absence of data, the use of empirical models which, for their successful application, require the assumption of uniformity for all variables except the one under investigation is common. While this degree of uniformity may exist in areas where the regional geology, geomorphology and climate do not vary significantly

FIGURE 8



A hythergraph which illustrates the relationship between the mean monthly temperature and mean monthly precipitation. The majority of the precipitation occurs during the period November-June, much of it in the form of snow. The months of July-September are extremely dry.

over wide areas, it is unproven that the approach has any particular merit when applied to mountain watersheds. The approach I have used in assessing the water balance of the Red Canyon Creek watershed is based upon a very limited amount of empirical data and a number of sometimes rather tenuous extrapolations of these data, based upon my experience and the limited amount of theory available dealing with the physical characteristics of the mountain environment. It is fundamentally in terms of the so-called "hydrologic equation", which represents an attempt to algebraically balance all inputs, outputs and storage which influence the system and which assumes that over time spans measured in years the balance of the terms is very close to zero. For any given water year, of course, this need not be the case.

INPUTS TO THE SYSTEM

In the hydrologic equation, inputs are considered to be 1) precipitation, 2) surface inflow and 3) inflow of subsurface waters. In the case of Red Canyon Creek, the question of whether or not subsurface inflows exist and, if they do, their volume contribution, remains unresolved; there are no apparent surface inflows to the basin; and, data relating the precipitation trends and patterns within the confines of the basin itself are extremely limited. These latter data are restricted to a series of snow depth measurements made by Ski Yellowstone Corporation along the east flank of Mt. Hebgen and in the valley floor near the proposed Village site. Offsite data consist primarily of the measurement of precipitation and temperature trends at climatological stations maintained at West Yellowstone, Montana, ten miles to the south of the Canyon at an elevation of 6650 feet a.s.l. and at Hebgen Dam, some five miles west of the Canyon, at an elevation of 6550 feet a.s.l. The analysis of the meteorological inputs to the hydrologic system of Red Canyon Creek is based largely upon these three sets of data. This section is not intended to be a climatologic evaluation of the area, which will be covered in detail in a separate portion of the report.

The form (solid or liquid) in which precipitation occurs is of vital importance in determining its eventual disposition within a watershed. In considering the data available from the stations at West Yellowstone and Hebgen Dam, an attempt has been made to relate precipitation and temperature in such a way as to show the relative percentage of the annual total which may be expected to fall as snow and as rain. This is done in the form of a hythergraph, shown in Figure 8. Here, it is assumed that most precipitation falling at mean monthly temperatures below 32°F (0°C.) will occur as snow while above that temperature, it will be in the form of rain. This is a crude breakdown which completely ignores the control exerted by elevation on mean monthly temperatures and differences of individual storm temperatures, but it represents a reasonable first approximation for determining the relative contribution of the two forms of precipitation to the regime of Red Canyon Creek. From the hythergraph, it can be seen that there are two wet periods during the course of the year in the vicinity of the study area. These are the periods November-March and May-June. During these two periods, over 75% of the total annual precipitation occurs. Of the total amount, slightly over 50% falls during those months when it can be expected to be in the solid phase, November-March. The mean annual totals for the two

FIGURE 9

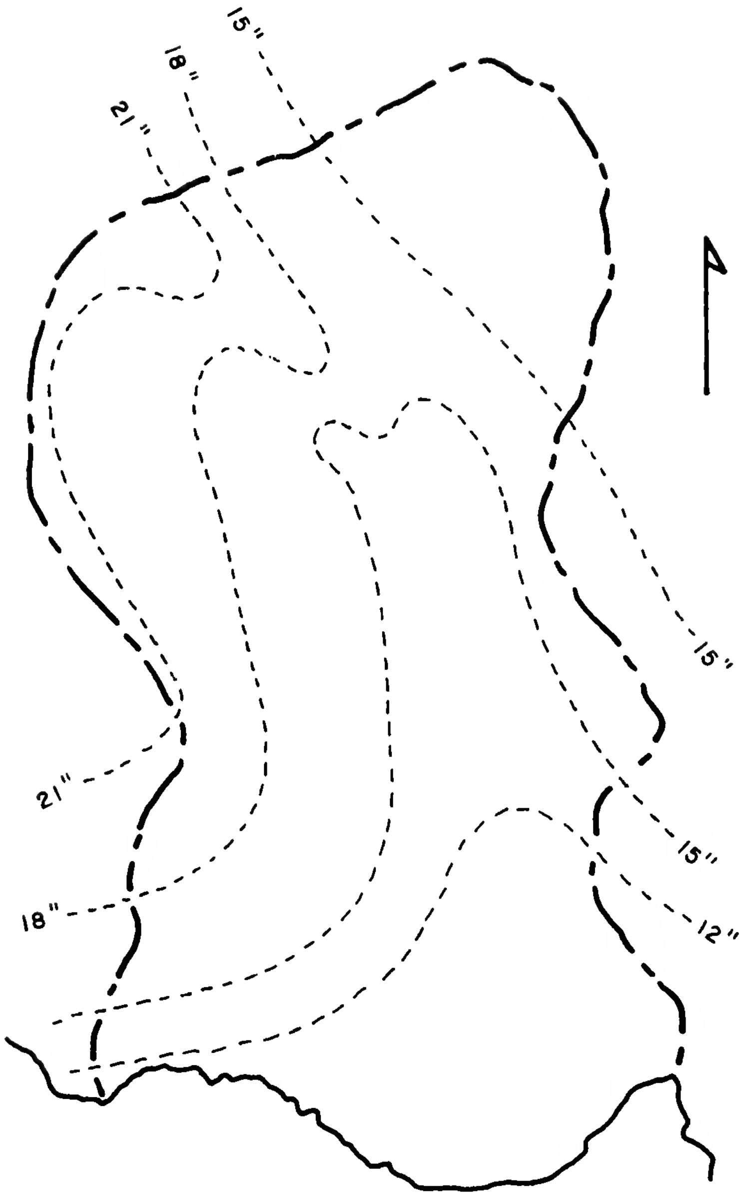


Figure 9. The isohyetal pattern for the winter snow pack developed from data supplied by Ski Yellowstone Corporation and based upon the assumptions discussed in the text. Values are given in inches of water equivalent and are intended to represent the long-term mean for the basin.

stations for the period of record are: West Yellowstone 21.22 inches water equivalent; and Hebgen Dam 25.84 inches water equivalent.

The primary problem involved in extrapolating these data into the Red Canyon Creek watershed concerns that of estimating the amount of spatial variation in the primary processes which control the form, amount and distribution of mountain precipitation. Using snow depth data collected by the Ski Yellowstone Corporation during the winter of 1972-73, an attempt was made to approximate the snow distribution pattern within the confines of the watershed, based upon the following assumptions: 1) isohyets (lines of equal precipitation amounts) of snow accumulation are sub-parallel to the contour pattern in mountainous areas; 2) at any given time, the bulk density of the snow pack is spatially uniform, reaching a maximum of between 30% and 40% water at the beginning of the melt season; 3) that the primary control on precipitation amounts for any given slope exposure is elevation 4); that precipitation amounts increase with elevation to the ridge crests in the study area; 5) that the main storm trajectory in the area is southwest to northeast; and 6) that snow accumulation ends on approximately the same date at all elevations in the basin. All of these assumptions are open to question, each to a greater or lesser degree, and have been listed here, not in the expectation that they will be universally accepted by those that read this report but rather to demonstrate something of the complexity of analyzing even a single element in the hydrologic balance of a mountain watershed.

Based upon the above assumptions and the fact that the winter of 1972-73 produced only approximately sixty percent of the long term mean precipitation amount at the Hebgen Dam climatological station, isohyets of the presumed mean annual winter (roughly, November-March) snow accumulation in inches of water equivalent were drawn for the basin (Figure 9). Since all of the data on which this isohyetal map was drawn were located on or near the east slope of Hebgen Mountain, the control is greatest in that area. Based on this speculative map, the mean winter precipitation of the Red Canyon Creek basin, as determined by planimetry, is between 15 and 18 inches of water. This amounts to between 8000 and 9000 acre-feet of water which are added annually to the system in the form of snow during the months of November-March. Since this period represents roughly fifty precent of the annual total, it is suggested that between 15,000 and 20,000 acre-feet represents a reasonable estimate of the total meteorologic contributions to the hydrologic balance of Red Canyon Creek annually.

Other than the potential subsurface inflows to the basin such as that believed responsible for Coal Creek, it is not believed that there are any other major contributors to the water reserves of the study area. 15,000 to 20,000 acre-feet is felt to represent the total annual addition to the system. The presence or absence of subsurface flows is, at least in part, an academic question since the total water requirements of the facilities to be developed in the basin represent less than 3% of the calculated annual meteorologic receipts (based upon estimates developed by the engineering firm responsible for water supply planning and assuming daily consumption at the maximum rate of use).

OUTFLOWS FROM THE SYSTEM

There are three main ways in which the inputs discussed above may leave the confines of the Red Canyon Creek watershed. These are: 1) surface outflows, 2) subsurface (or groundwater) outflows, and, 3) evapotranspiration. It is probable that all three processes contribute to the removal of water from the

study area. In determining the outflows from a basin, it is a common hydrologic practice to measure at least one of the above terms and treat the other two as residuals, the value of which is approximated in terms of assumed properties or other physical controls within the basin which act upon them. In the present instance, all must be considered as residuals in the hydrologic equation since it was not possible to complete a series of completely definitive measurements on any one of the three.

During the summer of 1973, a majority of the data collection efforts which were undertaken as a part of this study were expended in determining the characteristics of surface outflows. A somewhat lesser effort was directed toward a measurement of evaporation rates within the basin and, as of this writing, nothing but educated guesses are available concerning subsurface water distribution and movement.

On June 6, 1973, a recording water level gauge was installed on Red Canyon Creek in Section 2, R4E, T12S, and operated at that site until July 1. It was the primary purpose of this gauge to measure the diurnal variations in streamflow volume during the end of the snow melt period, to determine storm-associated flow variations and to understand something of the normal regime of the Creek,

In considering the surface outflows from the study area, it is necessary to evaluate both the rate and volume of flow. In terms of the rate of surface outflows, it is useful to point out here that the hydrologic regime of the study area is primarily one of snow melt hydrology, a subject which has received relatively little theoretical consideration in the literature. The timing of outflows from a basin dominated by processes of "thermodynamic" hydrology have no necessary relationship to the timing of inputs. Thus, in the Red Canyon Creek area, while over 50% of the annual precipitation occurs during the winter months, outflows during this period are reacting as if a drought situation existed. Some 75% of the total annual surface outflow from the basin occurs during the spring months of May and June, totally independent of any inputs to the system.

Hydrologically, the winter snows represent a reservoir which, if the skiing is to be of high quality, must remain in the solid phase throughout the ski season. Liquid input from this source is confined to the spring months. Preliminary evaluations suggest that the spring melt season (i.e. from the time the snow pack becomes isothermal at 0° C until it is no longer a significant contributor to surface runoff of groundwater reserves) lasts between 45 and 60 days. Because snow melt is a thermodynamic process, requiring thermal energy for its initiation and maintenance, it is apparent that melt will be some function of the total energy available to the snow pack at any given time. Perhaps less apparent is the fact that this thermal energy is received largely at the upper surface of the snow pack, through the processes of radiation, convection and conduction and therefore, the total surface extent of the snow pack at any given time is as important in determining total volumes of melt water production as is the energy which is available. The exact nature of the mechanisms controlling energy exchange between the atmosphere and the snow pack are complex. There have been a number of empirical equations developed which attempt to relate snow melt water production to various air temperature indices but they make so many simplifying assumptions concerning the nature of the exchange

FIGURE 10

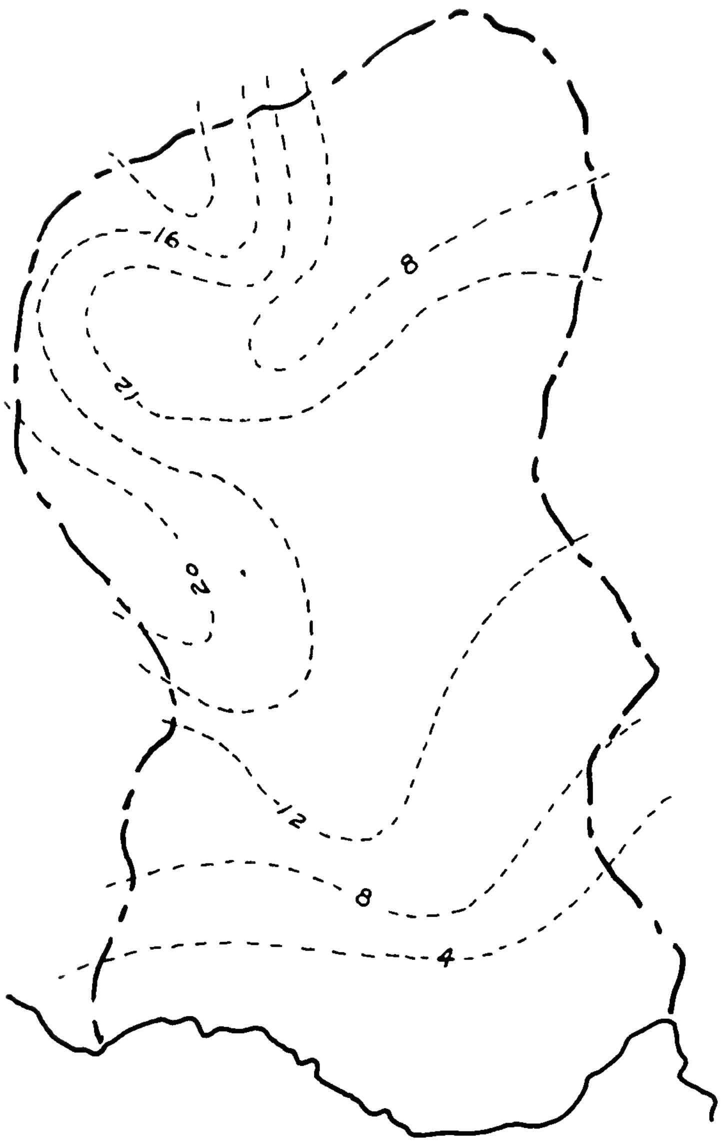


Figure 10. The postulated pattern of the basin snowcover one month after the pack has become isothermal at 0^{o} C in the Spring. Note that a majority of the melt has occurred on the alluvial fan and in the northeastern corner of the basin.

FIGURE 11

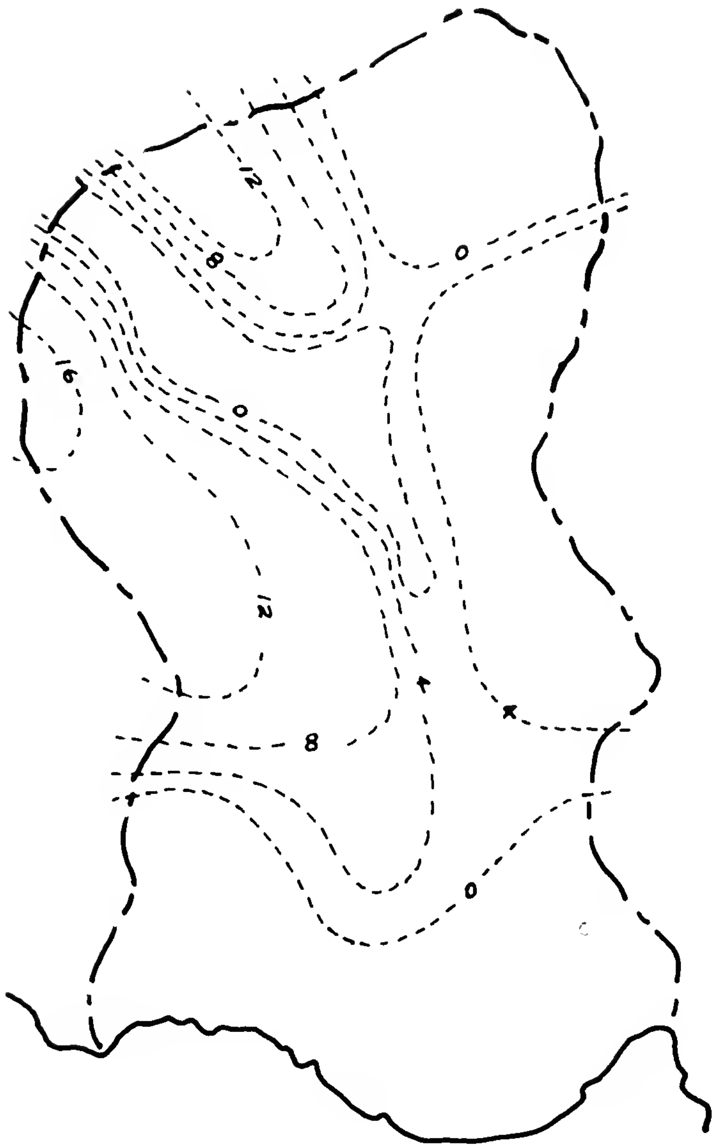


Figure 11. The postulated pattern of the basin snowcover forty-five days after initiation of Spring melt. By this time, the only extensive snow deposit lies on the north-east facing slopes of Mt. Hebgen. The final snowdrifts to disappear each year will be those on the north slope of Kirkwood Ridge.

processes that they cannot be applied with any confidence. While radiation, convection and conduction are involved to some extent at various times during the melt season in the study area, at the elevation and latitude of the area it is a reasonable first approximation to assume that all melt is the result of incident short-wave radiation.

Approximately 80 calories are required to convert one gram of ice at 0°C to one gram of water at the same temperature. Assuming a value of approximately 50% as the mean of cloud cover and snow albedo, the number of calories available at the elevation and latitude of the study site can be approximated theoretically. It will range from no melt on north slopes early in the season to in excess of one inch of melt water production each day on south slopes in June. Two maps (Figures 10 and 11) have been prepared, based on calculations incorporating the assumptions listed above and the initial snow deposition pattern shown in Figure 9, to show the expected pattern the snow cover in the study area will take: one month after the initiation of melt (Figure 10), and forty-five days following this date (Figure 11). Because the date on which snow melt will begin each year is dependent upon a complex of meteorologic controls, it cannot be specified with any precision, although it should normally fall somewhere between March 15 and April 15. An inspection of Figures 10 and 11 will show that within 45 days after the initiation of melt, the areal extent of the snow cover in the basin will be less than 50% of the total surface area and the annual spring flood should occur within this period in spite of the fact that the energy supply continues to increase throughout the melt season. It is estimated that the mean value of melt water production at the time of maximum surface snow cover coupled with maximum available energy for that period will be in the vicinity of 0.5 inches per unit area (the "specific" melt), or some 250 acre-feet per day.

Surface runoff during this period will very directly reflect variations in the rate and volume of inputs. Slightly before the onset of the melt season, Red Canyon Creek should be running near a base flow of 5-10 cfs. Following the beginning of snow melt, the level of the Creek will begin to rise at a rate which will be determined almost completely by the amount of energy available for melt. Regardless of the rate of rise however, the Creek will reach a peak in the vicinity of 100 cfs within approximately thirty days and begin to recede again. The exact volume of water involved in the peak flow will depend on the water-equivalent depth of the snowcover and whether or not spring rain storms coincide with this period. A heavy rainstorm, occurring during the period of peak snow melt, could increase the flow of the Creek by at least an order of magnitude (to approximately 1000 cfs) by depositing two to three inches of water uniformly over the floor of the basin. This juxtaposition of rare events, i.e. very heavy rains occurring at a particular time, would bring about what engineers refer to as the "hundred-year" flood. I have undertaken an analysis of some of the available precipitation records of the region in which Red Canyon Creek lies (Figure 12) and, statistically, at least, it is possible for rainfall amounts of the magnitude necessary to produce serious flooding to occur in the study area. The only significant rainstorm to occur during the period when the recording water level gauge was installed and which produced an estimated one inch of precipitation, caused only a very minor rise in the volume of stream flow. At the time of its occurrence, the annual snow melt period had ended. The Soil Conservation Service of the U. S. Department of Agriculture has calculated the magnitude of the "twenty-five" year flood for individual watersheds in the

FIGURE 12

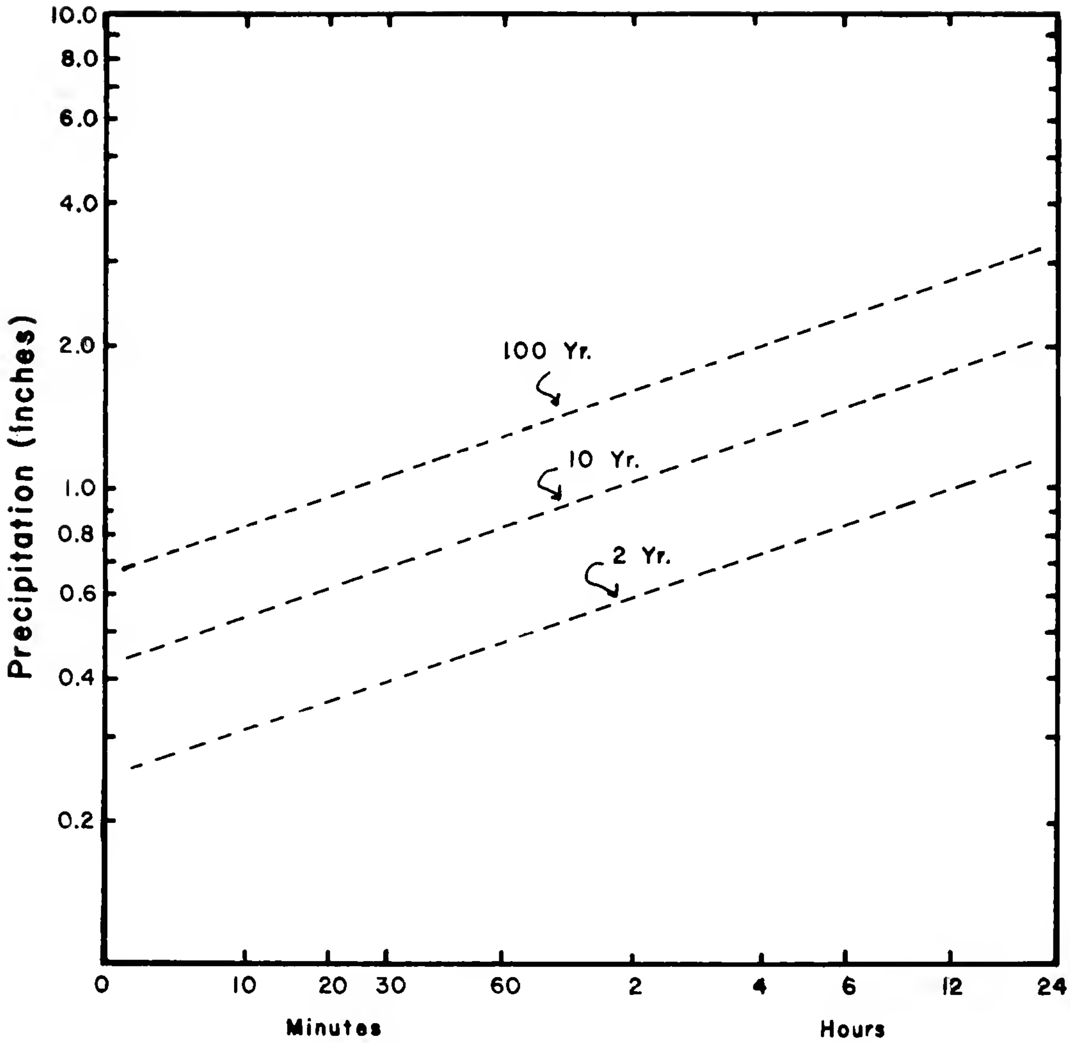


Figure 12. The two-, ten-, and one hundred-year return periods for precipitation amounts and durations based upon a statistical analysis of regional data.

FIGURE 13

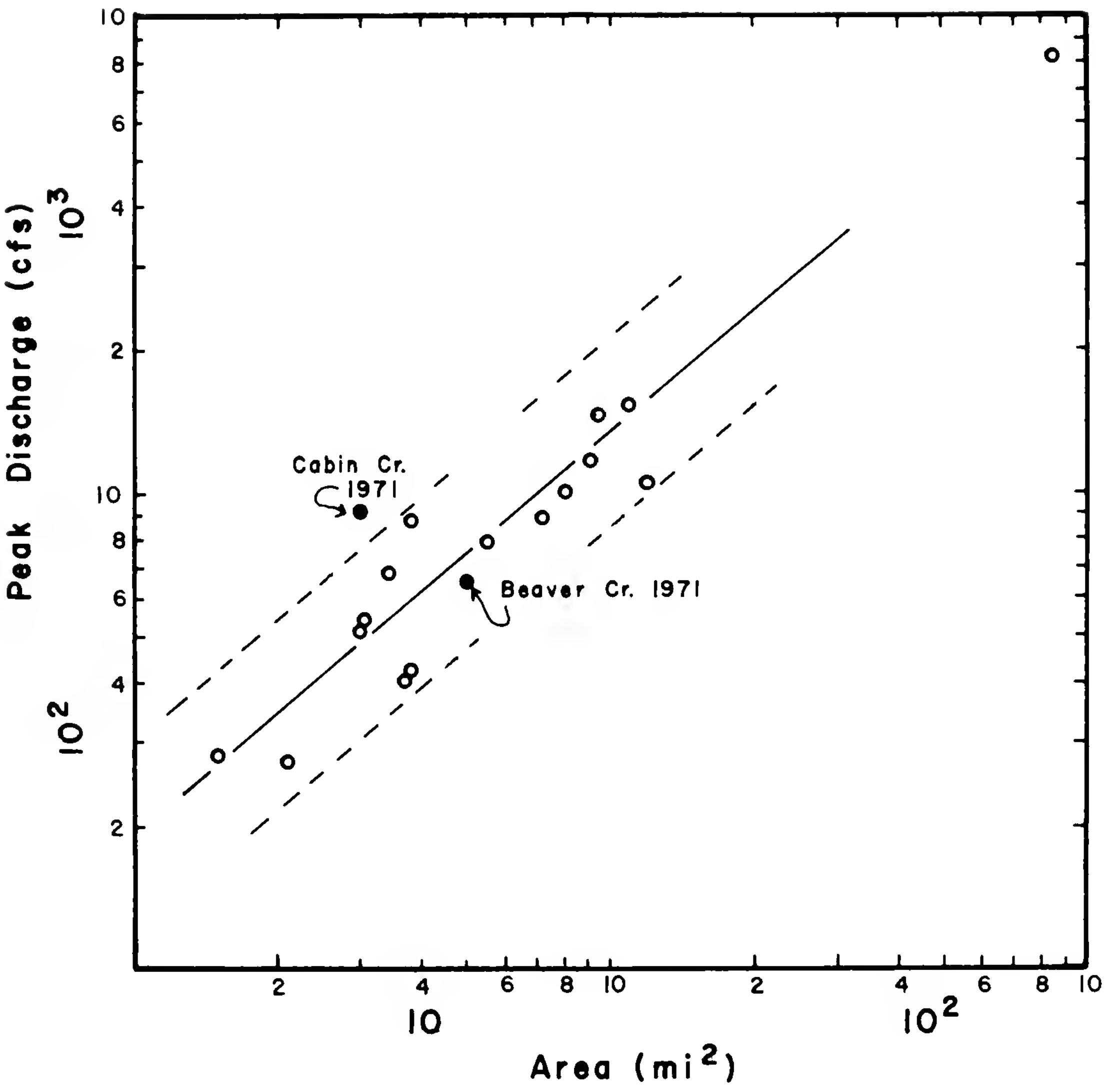
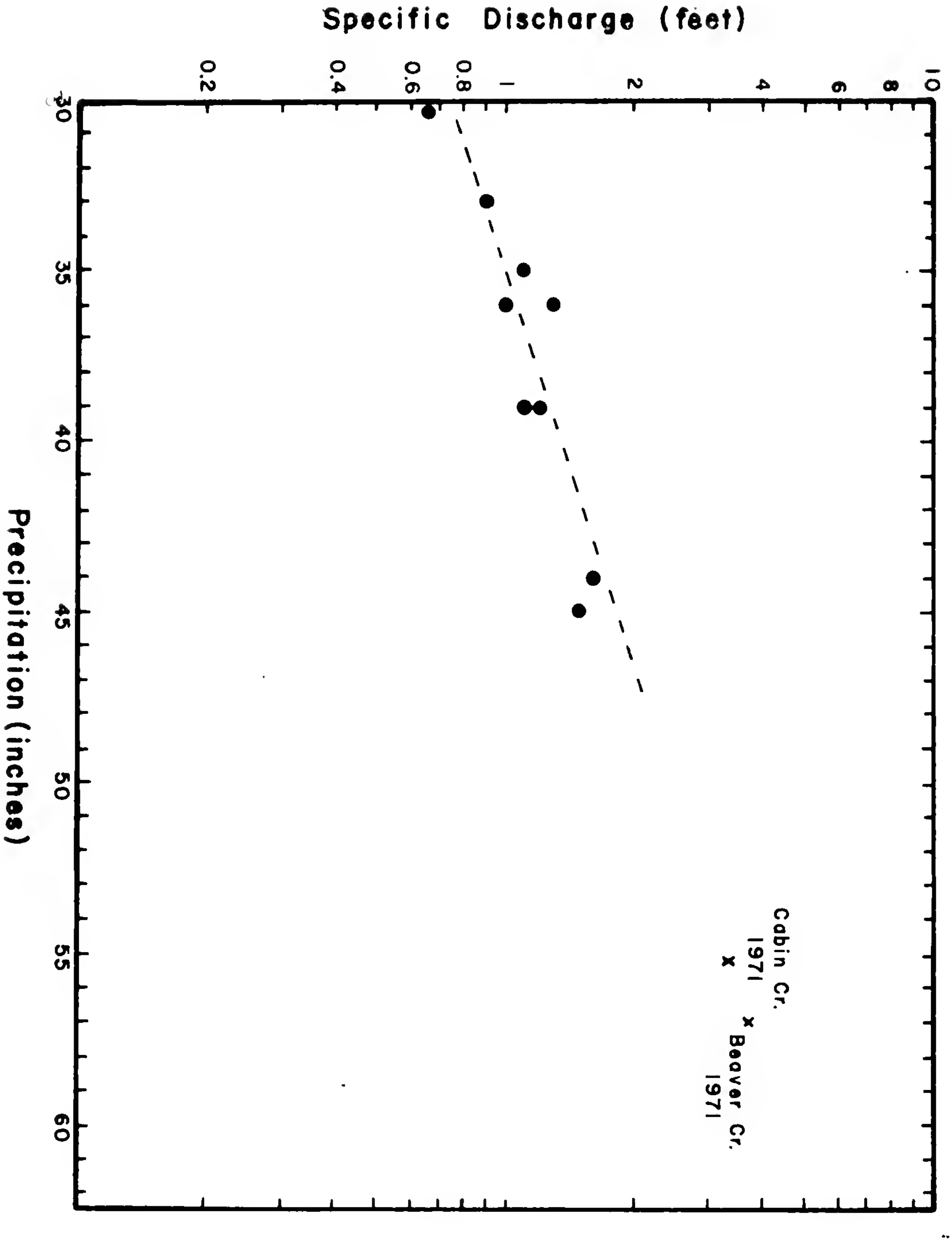


Figure 13. The "twenty-five" year flood discharge versus surface area for watersheds in the upper Gallatin River drainage basin. Based on the extrapolation of this relationship, Red Canyon Creek should be expected to have a twenty-five year peak discharge of the order of 200 cfs.

FIGURE 14



The relationship between specific discharge and annual precipitation for watersheds in the Gallatin River drainage basin, as calculated by the Soil Conservation Service. This relationship suggests that the Red Canyon Creek watershed will have an average specific discharge of near one foot of water annually.

Gallatin River drainage basin which lies to the north and east of the study area. These calculations are based upon a limited amount of empirical data and assume that watershed surface area is a useful indicator of flood volumes for watersheds located in a given region (which will presumably have comparable topography, geology and climate). They postulate that the relationship shown in Figure 13 exists for that drainage basin. Two streams, Cabin Creek and Beaver Creek, which drain into the Madison River immediately to the west of Red Canyon Creek are presently being monitored by the Forest Service, U. S. Department of Agriculture. The peak discharges measured during the spring of 1971, which, according to U. S. Geological Survey records could be considered to approximate the "twenty-five" year flood have been plotted on Figure 13 and it can be seen that there is a reasonable degree of agreement. In terms of the relationship shown in Figure 13 it can be suggested that the "twenty-five" year flood at Red Canyon Creek would be of the order of 200-250 cfs.

The approximation of a solution to the hydrologic equation for the study area required that some attempt be made to evaluate the volume of water which annually passes out of the basin as surface discharge. Based upon an analog approach, in which the Red Canyon Creek watershed is considered to be similar to others in the general region and assuming a mean annual specific precipitation value of between 30-35 inches for the basin, the Soil Conservation Service analysis of Gallatin River watersheds suggests that the study area should have a mean specific surface discharge of approximately one foot. This estimate is based upon a comparison of the values given for specific discharge and annual precipitation and is based on long-term means of each. This relationship for the Gallatin watersheds is shown in Figure 14. The 1971 data for Beaver Creek and Cabin Creek, tributaries to the Madison River, which were supplied by the U. S. Forest Service, have been added to this Figure. Since 1971 was presumably a year of higher-than-average runoff, the data sets are not strictly comparable and the high specific discharges exhibited by the Madison River tributaries for that year are presumably above their mean values. Assuming, as was done in an earlier section of this paper, that the effective surface area of the Red Canyon Creek drainage basin is ten square miles (6400 acres), a mean specific discharge of approximately one foot of water will result in a total surface outflow of some 6000-6500 acre-feet or roughly 30% of the total calculated inputs to the system. This is less than 1% of the volume of water which passes through Hebgen Lake, into which Red Canyon Creek drains, annually, according to flow records kept at Hebgen Dam. Calculations based upon the limited amount of streamflow data which were obtained from the recording water level gauge during the summer of 1973 on Red Canyon Creek give results which are in reasonably good agreement with those of the Soil Conservation Service. 6000 acre-feet of surface outflow represents a useful first approximation of the mean annual surface discharge from the study area. This leaves some 10,000-15,000 acre-feet of the calculated inputs to the system unaccounted for. This volume of water presumably leaves the basin as evapotranspiration and subsurface flows. It was not possible to measure either of these elements of the water balance of the study area directly in 1973. Their potential importance can be discussed only in the most general terms.

Estimates of the amount of evaporation for the region in which the study area lies range from 20 to 50 inches of water annually, of which some 80% occurs during the months May-October. Because of the annual distribution of precipitation with time in the study area, the summer months, when evaporation should be at a maximum, are the months when only a limited amount of water (approximately ten inches) is directly available at the surface for evaporation. It is probable that a majority of this summer precipitation is almost immediately evaporated and has little or no effect on the hydrologic budget of the basin but it is doubtful if a great deal more than this amount is lost by the process of evaporation. If this is the case, then an additional 5000 acre-feet of water are lost from the calculated inputs by this route, leaving some 5000-10,000 acre-feet to pass out of the study area as subsurface flows annually. While these estimates are admittedly crude, and could be refined considerably by more detailed additional studies in the area, it is felt that they represent a reasonable basis on which initial planning may be based and in terms of which the hydrologic impacts of the project may be assessed.

There are a large number (20-30) of springs within the confines of the watershed. I feel that only two -three of these have any real significance to this study as the majority may more properly be categorized as seeps originating from the Mississippian limestones at the point of contact with one of the shale units with which it is interbedded. Of somewhat more importance are: 1) the spring (or springs) from which "Spring" Creek originates and which contribute an estimated 50 - 100 gpm to the flow of Red Canyon Creek, 2) A spring in Section 2, R4E, T12S (sub-basin #7) which is associated with the Madison limestone - Wolsey shale contact and which, at the time of measurement, (ca. July 25, 1973), was producing 60 gpm. The importance of this spring, and that from which "Spring" Creek issues, lies in the possibility of development as a secondary source of water for either the Core Village or secondary developments. Either of these springs would be a source of over 70,000 gallons per day and thus, warrant some consideration as significant water sources. The third spring which lies within the Red Canyon Creek watershed, on the very eastern margin, is Corey Springs. According to the U. S. Geological Survey, Corey Springs has a reasonably uniform discharge of some 7000 gpm which, over the course of a year, is approximately 10,000 acre-feet. This value is in order-of-magnitude agreement with the calculated sub-surface flow from the basin and, hydrogeologically, appears to be associated with the limestones which are felt to be the primary subsurface conduit.

THE POTENTIAL FOR IMPACTS

Any discussion of the interaction between a development in a mountainous environment and that environment must be largely subjective. From the hydrologic standpoint, the potential for impacts of a ski facility on the east slope of Mt. Hebgen in the Red Canyon Creek watershed probably fall into a limited number of categories: 1) impacts on the timing or volume of surface runoff; 2) impacts on the groundwater supplies of the region; 3) increased sediment transport by surface waters; 4) pollution of surface or subsurface water; and 5) changes in water-related systems such as the biota of the area. Very broadly speaking, I doubt that the impacts of the development in any of these areas will be significant enough to be detectable to the casual observer. In fact, I suspect that,

without a lengthy series of very detailed, precise measurements, it will be impossible to prove that the development exists at all, considered solely from the hydrologic view. In terms of each of the categories listed above, it is probable that some changes will occur. It is virtually a tenet of mountain environmental analysis, however, that annual fluctuations about the mean of any property of the mountain environment are extreme (this, of course, applies only to those which are not "fixed" such as topography or bedrock geology) and that, in order to have a noticeable impact, it is necessary that the activities of man produce an effect which either augments or exceeds the natural variability of the system. Specifically, in terms of the categories listed above, it is suggested that the following impacts will probably result. This listing is based upon my present understanding of the project design and could be changed by significant alteration of present plans. The development will produce two changes in the watershed which could lead to changes in the runoff pattern. These are: 1) timber removal during the construction of ski trails which will have an effect on snow accumulation and melt and on evapotranspiration amounts and 2) the paving of areas in the Core Village area for parking lots, etc. Since the area has been logged commercially on several occasions over the years, the Corporation presumably does not intend any extensive program of timber removal since most of the logical skiing routes are already clear. In order for timber removal to have a noticeable impact, it would probably be necessary to remove trees from several hundred acres, at a minimum. It is my understanding that this amount of acreage is not involved. Paving of the areas in and near the Core Village area is expected to have even less impact since this site is located outside the effective area of the watershed and may produce an increase of some 50 acre-feet of surface runoff annually which under natural conditions would enter the water table or be evaporated. This volume is insignificant in comparison with the natural annual volume of runoff.

It is expected that the primary domestic water supply for the ski facility will be developed from the groundwater reserves of the basin as this represents the most dependable source of water. Preliminary estimates by the engineers and planners suggest that the water requirements of the development will reach a maximum of slightly in excess of 400,000 gallons per day. Using this value as the mean daily consumption for the entire year, gives an annual usage of approximately 400 acre-feet. This represents less than 10% of the calculated amount of water passing through the groundwater reserves annually and, if one considers that Red Canyon Creek is effluent and therefore that the surface flows are intimately linked to the groundwater reserves, it represents less than 5% of the total potential upon which the development may draw. Since this resource is renewed annually, I doubt that the removal of even 10% on an annual basis will have any significant impact on the groundwater table of the basin. Since it is quite probable that the groundwater in the study area is totally independent of any regional water table (due primarily to geological considerations) there should be no regional impact.

Sediment transport in Red Canyon Creek occurs only during the spring snow melt period and the sediment is derived wholly from the sub-basin in which the Creek originates (sub-basin #1, Figure 3). Since there are no development plans for this portion of the watershed, there will presumably be no impact on the volume of sediment transported annually. During the spring melt period, the

sediment load of the Creek is sufficiently high (perhaps up to 5000 ppm of suspended clays and silts) to preclude any use of the surface runoff by the developer. Any manipulation of the present stream profile, such as the creation of ponds along its channel, would probably result in considerable siltation each spring in the artificially-created settling basins. It is felt that the stream is presently well-graded and modifications of the channel should only be undertaken with extreme caution.

In this respect, there is one exception to the statement that the stream channel should not be modified. A series of preliminary east-west profiles drawn across the alluvial fan using a 1:6000 photogrammetric map indicated that the present master channel in the vicinity of the proposed village site may be some twenty feet higher than the most prominent of the abandoned channels. While this elevation difference may be more apparent than real and result from errors in elevation controls used in the production of the map, if it is real some thought should be given to re-routing the stream into the main western channel. This is a major step and cannot be undertaken lightly. As a first step, certainly, the accuracy of the base map should be checked by a series of on-site level lines. Whatever the final decision however, both channels must be available for flood routing.

Field evidence suggests that two types of flooding may have occurred in the recent past. These are: 1) sheet flooding over the surface of the alluvial fan, and 2) exceptionally high volumes of flow in the two main master channels incised into the fan. Under uncontrolled conditions, it is apparent that Red Canyon Creek has shifted its location on the fan suddenly in the past. There are at least four abandoned channels incised into the lower portion of the alluvial fan. The reasons for these sudden shifts are not apparent and may include earth movements which create temporary dams, the activities of beavers, warping of the fan due to earthquake activity, bank erosion at some topographic high along the stream channel or some combination of these. Whatever the cause, it appears that these periods during which time a new channel is being established may have been characterized by sheet flooding across the fan. This assumption is based on the fact that each of the abandoned channels is a distinct and separate feature and no evidence of gradual, lateral planation from one to another exists. The possibility of sheet flooding occurring at any time in the future can probably be largely eliminated by ensuring that the Creek is stabilized in one of the two primary master channels incised into the lower fan. Because of the probability that sheet flooding has occurred in the past, the entire lower fan from slightly upstream from the contemplated village site is considered to be a zone of moderate flood potential.

Flood debris which I observed in both the primary master channels suggests that each has carried a volume of water sufficient to almost completely fill it in the past. Rough calculations, based upon measured cross-sectional areas of the channels (approximately 250 ft^2) and estimates of flow velocities (5-10 fps) suggest that at some time, a flood of 1000-4000 cfs has occurred. The actual magnitude depends upon whether or not both channels were involved simultaneously and the values assigned to flow velocity. Primarily on the basis of these observations and calculations, I feel that the immediate vicinity of each of the

primary master channels should be considered to be a zone of high flood potential which can be lessened by proper engineering practices. These would include ensuring that both primary master channels in the lower fan were available for flood routing and that no construction encroached upon any of the abandoned channels (see Appendix for location of flood zones).

The potential for water pollution, while it exists, can be largely eliminated by sound engineering of the sewage disposal system. As of this writing, plans for this system have not been completed but the developer is aware of the problem and I foresee no detectable degradation from this source.

The extent of changes in the biota resulting from changes in the hydrologic regime of the system discussed in this paper is more in the province of the biologist than the hydrologist. I would not anticipate any changes which were directly traceable to the minor impacts which the development will have on the hydrology of the basin.

In view of the possibility, however slight, that unforeseen elements of the development may have adverse effects on the hydrologic regime of the Red Canyon Creek watershed, I feel that a limited monitoring network of hydrologic instrumentation would be of value. Not only would it allow a determination of actual changes which occur in the watershed as a direct result of the developers activities with time, but also it would serve to provide the developer with advance information on such changes so that appropriate action could be taken. Ideally, this instrument network would consist of: 1) a Parshall flume and water level recorder located somewhere on the lower portion of Red Canyon Creek to obtain a continuous record of surface streamflows, 2) a monitoring well equipped with a water level recorder to provide information of groundwater drawdown within the immediate vicinity of the Core Village, and, 3) a number of snow courses established within the confines of the basin, particularly in sub-basins #1, and #2, so that qualitative predictions concerning the magnitude of the spring flood and the general hydrologic "health" of the basin may be made annually. I feel that this type of effort, which will involve a minimal investment and which could possibly be carried out as a joint venture between the developer and an interested government agency, such as the Forest Service, would serve both to show the development of potential impacts before they became critical and to allow the developer to adjust his activities so as to ameliorate the effects of these impacts, if any.

DAVE JOHNSON CREEK

Due to the relatively limited importance it has in the present plans of the developers, little effort was expended in a study of the Dave Johnson Creek watershed. I gained the following impressions from visits to the area and map inspection.

1. The watershed has a surface area of slightly more than one square mile (approximately 700 acres).

2. The stream, which during the period of observation was flowing at an estimated 1-2 cfs, is totally influent at the upper end of the alluvial fan. A surface drainage channel has been incised into the fan but is probably occupied only during periods of maximum floods.

3. By analogy with the Red Canyon Creek watershed to the east, it is estimated that some 2000 acre-feet of water pass annually through the Dave Johnson Creek catchment basin of which approximately one-third is lost by evapotranspiration, one-third passes directly into the groundwater system and one-third enters the groundwater system at the point of influence of the surface drainage.

4. The maximum flood to be expected should be of the order of 10-20 cfs. It should be confined to the existing channel.

CONCLUSIONS AND RECOMMENDATIONS

In terms of the degree of analysis which was possible for the study of the Red Canyon Creek watershed, I do not feel that there are any necessary or unavoidable impacts on the hydrology which will result from the construction of a ski area on Mt. Hebgen. My calculations indicate that the groundwater reserves of the basin are at least an order of magnitude greater than the projected water requirements of the project. While sewage disposal could present a problem if it is improperly handled, until the developers' plans for sewage disposal are in a more final form, there is no way in which the potential impact of this activity can be assessed. Two disposal methods which appear initially not to be detrimental are: 1) secondary treatment with subsequent spray irrigation of the lower alluvial fan so that the effluent is removed by evaporation (application rates would have to be controlled in this method, to prevent the possibility of surface runoff into Hebgen Lake but this presumably presents little problem) and 2) offsite ponding with effluent disposal by percolation into the floor of the pond and evaporation from its surface. In either case, more tests than were possible during the course of the study described here will be necessary before the most suitable alternative is determined but both appear feasible at the present time. A third alternative, that of spraying the secondary effluent on a south-facing mountain slope above the core village site is felt to warrant additional investigation if, for any reason, a need should arise to decrease the amount of surface area required to evaporate the sewage outflows of the facility.

Approximately 15,000 to 20,000 acre-feet of water pass annually through the Red Canyon Creek watershed. Of this amount, roughly one-third leaves the basin as surface runoff, one-third is lost by evaporation and one-third enters the groundwater reserves and ultimately leaves the basin as subsurface flow. The mean spring flood is of the order of 100 cfs and will occur each year in late May or June, depending upon the Spring weather patterns. The calculated "twenty-five" year flood is of the order of 250 cfs while the maximum flood to be expected from the basin will be between 1000 and 4000 cfs. In all cases, the drainage channel system presently incised into the alluvial fan should be sufficient to handle these flow volumes.

The groundwater reserves of the basin are presumably contained in the surficial alluvial fill and the limestones which constitute a portion of the bedrock of the area. All of these reserves, at least down to a line parallel to the mountain front on the south end of the basin, are believed to originate within the basin itself. South of that line, there undoubtedly exists some intermixing with the water table associated with Hebgen Lake. Without additional testing, there is no way to specify the properties of the aquifers or local variations in the flow and volume of the groundwater reserves.

Sediment transport by Red Canyon Creek will be a problem only during the Spring snowmelt period, when flow volumes will reach their maximum. However, any feature in the stream which decreases flow velocity during this period, such as a pond, will be subject to considerable siltation and should be avoided.

There are no withdrawals from the basin for agricultural purposes. The only present uses of the water of the basin are three wells drilled at various sites on the alluvial fan which are used to produce water for domestic purposes. There should be no conflict between any of these and the water requirements of the ski development.

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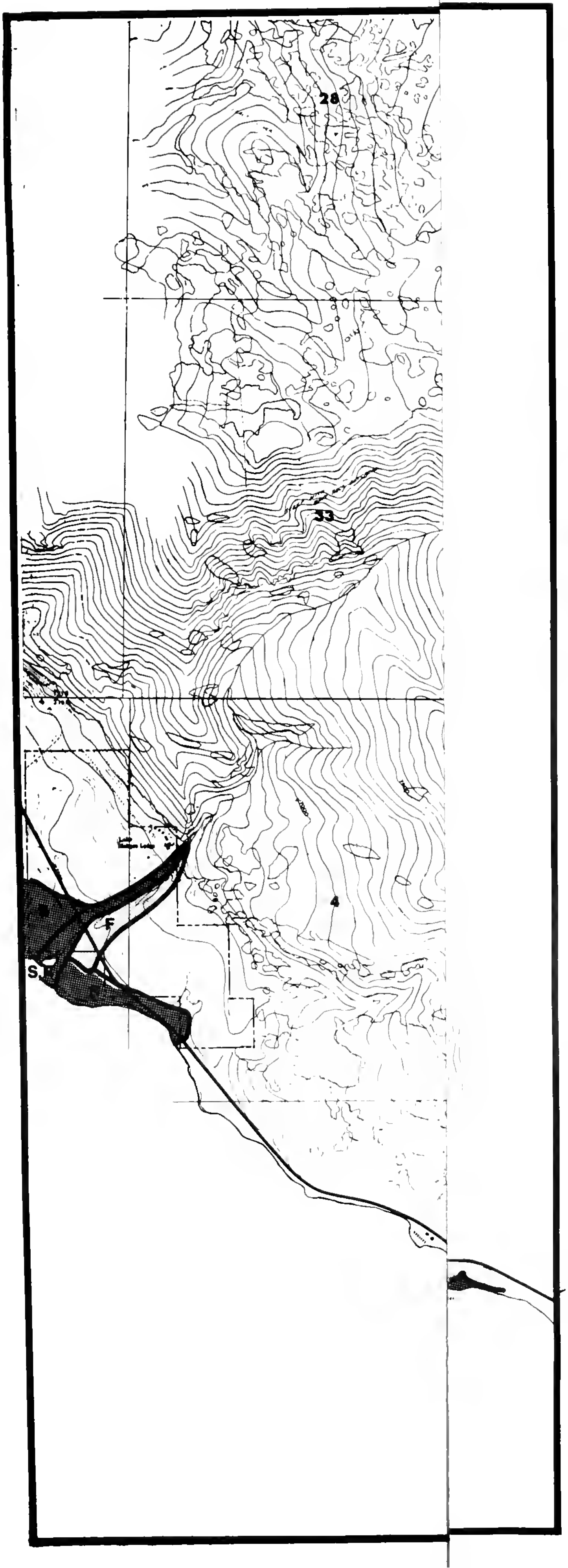
GLOSSARY

Acrefoot - The quantity of water required to cover 1 acre to a depth of 1 foot. Equivalent to 43,560 cubic feet or 325,851 gallons.

Cubic foot per second (cfs) - The rate of discharge representing a volume of 1 cubic foot passing a given point during 1 second. Equivalent to 7.48 gallons per second or 448.8 gallons per minute.

Aquifer - A waterbearing geologic unit.

Stream order (1st, 2nd, 3rd, etc.) - Level of succession in joining of tributaries within a drainage network. The smallest unbranched tributaries are first order. Confluence of two streams of the same order forms a stream of next higher order.



ENVIRONMENTAL SUMMARY

PRIMARY STUDY AREA

HYDROLOGY
DEVELOPMENT LIMITATION ZONES

BY DONALD ALFORD

LIMITATION TYPES

- CHANNELIZED RUNOFF
- SEICHE FLOODING: ASSOCIATED WITH SEISMIC ACTIVITY
- F — SHEET FLOODING: RESULTING FROM OVERFLOW FROM MAIN DRAINAGE CHANNELS
- QUESTIONABLE BOUNDARY

DEGREE OF LIMITATION

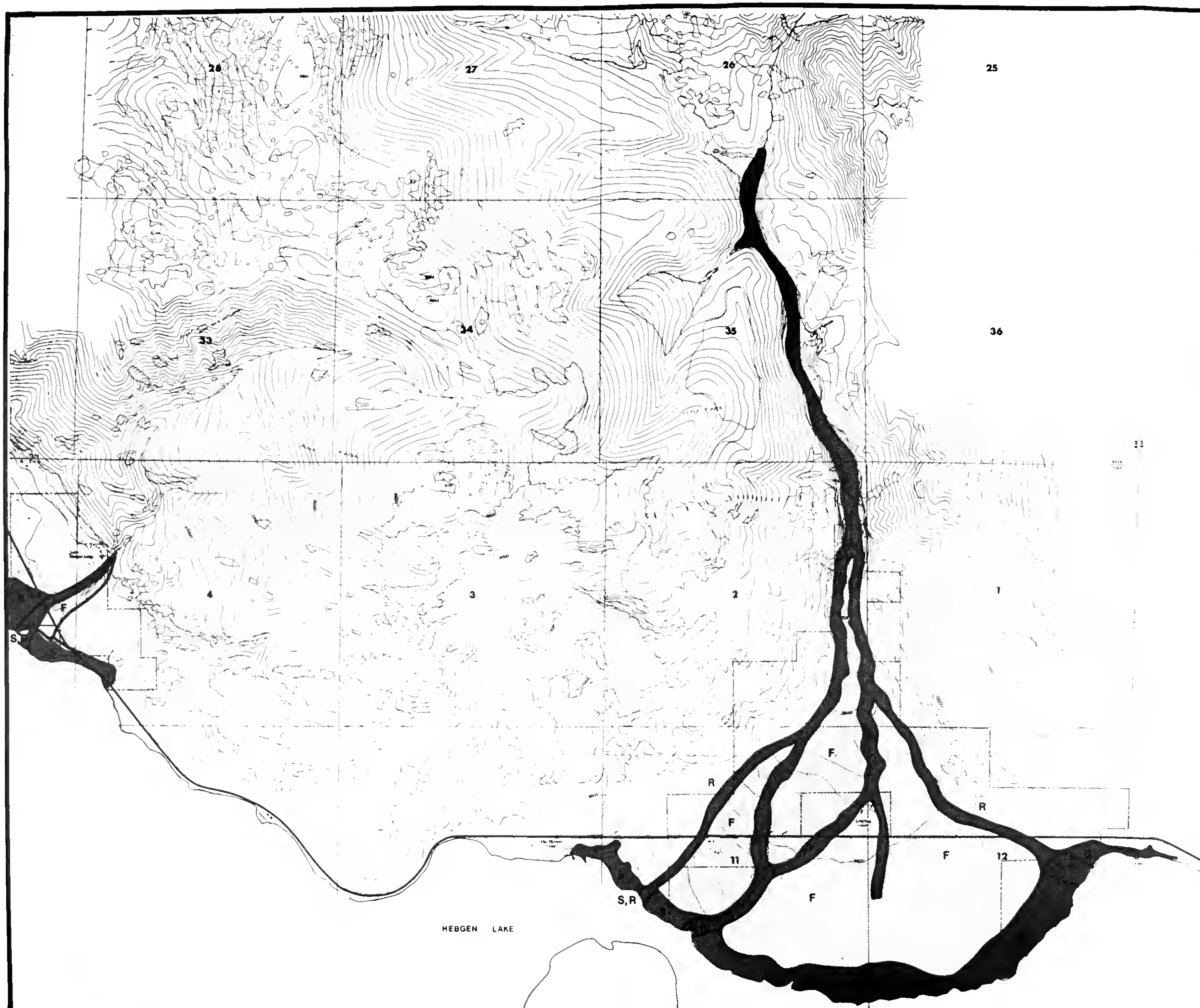
- HIGH INTERMITTENT
- LOW INTERMITTENT

SKI YELLOWSTONE

SKI YELLOWSTONE INC.

WEST YELLOWSTONE, MONTANA

SCALE 1" = 2000



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THE LIMNOLOGY OF THE GRAYLING ARM OF HEBGEN LAKE

John C. Wright

INTRODUCTION

Hebgen Lake is an artificial impoundment of the Madison River. During the normal annual high water period (June-July) the lake is approximately 15 miles long, 3 miles wide at the widest point, and has a total surface area of about 20 square miles. During high water, the lake has a maximum depth of about 80 feet. Maximum storage capacity of the reservoir is 377,500 acre-feet. Throughout an annual cycle, the water level in the reservoir undergoes an average vertical fluctuation of 20 feet.

Martin (1967) in an unpublished doctoral thesis discussed the results of an intensive study of the limnology of Hebgen Lake that was undertaken during the summers of 1964 and 1965. In 1964 data were obtained on temperature, electrical conductivity and light transmission in the Grayling Arm as well as four other stations in the lake. Intensive studies of water chemistry and plankton populations were made at a station off-shore from Hebgen Lake Lodge.

In discussing the hydrography of the lake, Martin noted that cool dilute water entered the main body of the lake from Grayling Arm. Grayling Arm water was then mixed with water of warmer temperature and higher conductivity that originated from the Madison River. The upper strata of water underwent significant increases in temperature and decreased in conductivity as it moved down-reservoir. Light penetration was also found to be progressively less in the Grayling than in the rest of the lake.

The present study was undertaken to ascertain water quality and plankton populations of the Grayling Arm specifically. In addition, chemical and biotic studies were made on the major tributaries of the Grayling Arm, i.e. Grayling, Duck, and Red Canyon Creek. As a surface flow Dave Johnson Creek has no effect on Hebgen Lake since it disappears into the ground several hundred yards from the lake shore. Results of studies on Dave Johnson Creek will be reported in J. J. Jezeski's section of the study.

METHODS

A sampling station was selected in the Narrows of the Grayling Arm. The station was located on a line due south of the west boundary of property owned by Ski Yellowstone. At this position the station was west of the mouth of Red Canyon Creek.

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A sampling station was selected in the Narrows of the Grayling Arm. The station was located on a line due south of the west boundary of property owned by Ski Yellowstone. At this position the station was west of the mouth of Red Canyon Creek.

Three sampling stations were selected on Red Canyon Creek. An upper station was located on the boundary between property of the U.S. Forest Service and Ski Yellowstone. An intermediate station was located at the highway culvert (Hwy 287) and a lower station was sampled near the mouth of Red Canyon Creek.

Samples were collected at the highway bridge (Hwy 287) over Grayling Creek and the highway culvert (Hwy 191) over Duck Creek.

Water samples were collected from Grayling Arm with a 2 liter Van Dorn water sampler. Samples were collected at the surface and at five foot intervals to a depth of 20 feet which was just above the bottom.

At each depth a 300 ml sample was collected for oxygen determination, a 125 ml sample was fixed with Lugols solution and a liter sample was collected for chemical analysis and chlorophyll determination. Temperature was measured with a thermistor and light transmission was determined by the use of a submarine photometer. A sample was obtained for zooplankton analysis by an oblique tow from 20 feet depth to the surface with a Clarke Bumpus plankton sampler.

As soon as possible an aliquot of water ranging from 300 to 500 ml was filtered through a millipore filter having a 0.45 micron pore size. The filter was dissolved in 5 ml of 90% acetone for chlorophyll extraction. The chlorophyll extracts were kept at 5° C in a light proof container. After extraction was complete the acetone solution was centrifuged and the optical density of the supernatant was measured with a Beckman DU spectrophotometer. From the optical densities measured at 665, 645, and 630 milli-microns wavelength of light the concentration of chlorophyll a was determined.

The filtrate from the millipore filtration was kept for colorimetric analysis. The remaining unfiltered water was kept for titrimetric analysis and conductivity measurement. A portable glass electrode pH meter was used for determination of pH. Oxygen concentration was carried by the Alstenberg modification of the Winkler method.

Of the colorimetric methods nitrate was determined by the cadmium reduction method, phosphate by the single shot ammonium molybdate-asorbic acid reagent, ammonia by direct nesslerization, silica by the high range acid-ammonium molybdate method, sulfate by turbidimetry and turbidity by absorption at wavelength 440 milli-microns.

Total hardness and calcium hardness were measured by complexometric titration, chloride by mercuri nitrate titration, and total alkalinity by potentiometric titration. Magnesium was calculated by difference between total and calcium hardness. Sodium and potassium were measured by flame photometry. Flouride was determined colorimetrically with SPADNS reagent.

Phytoplankton was determined by examining and counting the sedimented plankton contained in 5 ml chambers. An inverted microscope was used and on the basis of appropriate measurements the cell volume of phytoplankton species was calculated.

Five one ml aliquots of the Clarke Bumpus samples were examined under a binocular microscope for the purpose of enumerating zooplankton species.

Stream insects were collected by multiple plate samplers that were submerged for a month.

Stream algae were collected on plexiglass plates that were submerged for a month. Upon removal the algae were scraped from both sides of the plate and the chlorophyll content was determined.

RESULTS

Light Transmission and Turbidity

Light sufficient for algal growth in Grayling Arm was present at depths ranging from 3 meters (10 feet) to 7 meters (23 feet). Highest turbidity was present in June during peak runoff. Turbidity was also significantly high in late July due to a blue-green algal bloom. Of the three tributaries, Red Canyon Creek was the greatest contributor of silt to the lake. Turbidity was higher in the lower reach of this stream due to bank erosion during high water.

Temperature

No strong thermal stratification was observed in Grayling Arm, hence there was little resistance to wind mixing. Temperatures favorable to blue-green algal growth (above 14°C) were attained by mid-June. Temperatures of the tributary streams were below the recommended upper limit for trout of 20° C.

Oxygen

Although oxygen concentrations at 20 feet were lower than surface concentrations oxygen was in excess of the lower limit of 5 mg/l recommended for trout. Stream oxygen concentrations were well above this limit.

pH and Carbon Dioxide

Values of pH were lowest in Grayling Arm during June reflecting the higher concentrations of free carbon dioxide at this time. The higher carbon dioxide levels were correlated with the rise in lake level as a result of spring runoff. Since the higher carbon dioxide concentrations cannot be accounted for by stream runoff, it is presumed that they were a result of decaying organic matter flooded by the rise in lake level.

Water Quality

Duck, Grayling, and Red Canyon creeks are the major streams that flow into the Grayling Arm, however the Madison River has a greater effect on Hebgen Lake because of its greater discharge into the main body of the lake. Since the prevailing winds are westerly, wind induced currents mix Madison River water with water contributed by the Grayling Arm tributaries.

Three distinct chemical types are present as can be seen by examination of the following table.

CHEMICAL ANALYSIS OF HEBGEN LAKE TRIBUTARIES (JULY 6, 1973)

mg/l

	Ca	Mg	Na	K	HCO_3	Cl	SO_4	F	SiO_2	PO_4-P	NH_3-N	NO_3-N
Madison River	5.75	0.34	69.92	7.82	116.51	47.60	10.2	6.35	92.0	0.082	0.012	0.000
Duck Creek	12.20	1.80	5.98	1.33	56.10	1.25	7.5	1.01	27.5	0.020	0.03	0.042
Grayling Arm	18.20	2.50	1.84	0.78	68.90	1.00	3.0	0.48	15.0	0.005	0.06	0.014
Red Canyon River	140.80	21.40	10.58	2.19	146.40	2.00	248.0	0.90	8.0	0.005	0.02	0.014

Madison River water is a sodium-bicarbonate-chloride type with high concentrations of silica and higher than normal concentrations of potassium and fluoride

Duck and Grayling Creeks are calcium bicarbonate water whereas Red Canyon Creek is a calcium-sulphate-bicarbonate type. Red Canyon Creek has the highest content of total dissolved solids followed in order by Madison, Grayling and Duck waters.

Because of these chemical differences water masses in Hebgen Lake can be identified as to origin. High sodium, chloride, silica and fluoride content indicates Madison River water whereas high calcium water indicates Duck, Grayling and Red Canyon water. Red Canyon water can be differentiated from Duck and Grayling Creek waters.

Shortly after the disappearances of ice cover in early May and with the beginning of spring runoff the upper five feet of Grayling Arm water had obviously originated from Grayling Arm tributaries and overlaid water of Madison River origin. Phosphate-phosphorus concentrations were less than 0.01 mg per liter in surface water and greater than 0.22 mg per liter in the underlying water. Ammonia nitrogen was undetectable at all depths and nitrate-nitrogen concentrations were 0.01 mg/l from surface to bottom.

By the first week in June as a result of high discharge from snow pack melt the upper 15 feet of water in Grayling Arm had obviously originated from Duck, Grayling and Red Canyon Creek runoff. Madison River water was found only near the bottom where 0.02 mg per liter was present. In contrast to the behavior of phosphate ammonia-nitrogen levels had risen to 0.15-0.30 mg per liter and nitrate-nitrogen levels to 0.010-0.066 mg per liter.

With decreasing discharge in late June water quality became more dependent upon the effect of wind-driven currents. With westerly winds water more characteristic of Madison River water was forced into the Grayling Arm as was the case for June 15 and July 25. As a result of westwinds piling up water in the Grayling Arm a counter-current was set up that flows westerly below the surface. This situation is clearly evident from examination of the chloride data on July 25 where high chloride water is present in the upper five feet and lower chloride water is present below 15 feet.

Chloride data on June 15 and July 6 show the effects of easterly wind flow. Low chloride water characteristics of the Grayling Arm tributaries, overlies high chloride water brought into the Arm by a counter-current flowing from the west.

Ammonia-nitrogen concentrations ranged from 0.36 to 0.96 mg per liter on June 15 to 0.20 to 1.06 mg per liter on June 26. Nitrate-nitrogen concentrations ranged from 0.010 to 0.032 mg per liter on June 15 to 0.020 to 0.024 mg per liter on June 26. Subsequently, ammonia-nitrogen levels dropped to 0.06

mg or less on July 25 and nitrate-nitrogen levels to 0.010 or less.

The nitrogen levels observed in June were well above concentrations observed in the tributary streams. Since they were present when lake level was rising from its seasonal low to the high water stage the increase in nitrogen was almost certainly due to ammonification and nitrification of flooded organic matter.

Phosphate-phosphorus during the last half of June and July were higher than the phosphorus concentrations observed in the Grayling Arm tributaries. These higher levels were most certainly due to mixing of high phosphate Madison River water with Grayling Arm water.

Since Grayling Arm has a flouride content greater than 1.5 mg/l most of the time and Red Canyon Creek has a sulfate content greater than 250 mg/l during low flow neither can be considered as a source for potable water.

Phytoplankton

Maximum chlorophyll concentration of 42.59 micrograms per liter were seven times as great those measureed by Martin in the main body of Hebgen Lake. Maximum cell volume of 14.75 cubic millimeters per liter was more than two times as great as the maximum observed by Martin. The peak phytoplankton density was associated with the highest observed phosphorus concentrations and the lowest observed nitrogen levels.

The dominant species including three blue-greens (Lyngbya bingei, Anabeana Spiroides, Aphanizomona flos-aqua)and two diatoms (Asterionella formosa Fragilaria crotonensis) were also found to be dominant by Martin. Lyngbya and Anabenna were by far the most important. Although the in-organic nitrogen compounds present in June were almost completely taken up by the plankton in July the nitrogen-fixing proclivity of blue-green algae makes them independent of inorganic nitrogen compounds as long as adequate phosphorus is present. Because of its shallowness and higher ratio of bottom area to water volume Grayling Arm appears to be more productive of phyto-plankton than deeper portions of Hebgen Lake. The shallowness allows wind to mix water throughout the water column and promotes exhange of substances between the sediment and the overlying water.

Zooplankton

The same species of Zooplankton observed by Martin to chracterize Grayling Arm water were also observed during the present study. No great differences in abundance were noted.

Stream Flora

Duck Creek had the most diversified flora of all streams. Rooted aquatics particularly water-buttercups were abundant as well as a diatom coating on the substrate. Grayling Creek was characterized by a diatom flora and had no conspicuous rooted aquatics. During high water, plant growth in Red Canyon Creek was severly limited by the heavy silt load. After cessation

of high flow the upper reach of the stream was characterized by diatom growth. The lower reach had a very unesthetic growth of a filamentous algae (Vaucheria). Weed beds were present at the mouth. Based on chlorophyll concentrations that accrued on plexiglass slides the ability of lower Red Canyon creek to support algal growth was far greater than upper Red Canyon Creek, Grayling Creek and Duck. Duck Creek was slightly more productive than upper Red Canyon Creek and Grayling Creek.

Stream Insects

Duck Creek, Grayling Creek and upper Red Canyon Creek supported the normal may fly nymphal and midge fly larvae populations that may be expected in swift clean cold mountain streams. The insect fauna of lower Red Canyon Creek was very depauperate and restricted to midge fly larva that are tolerant of silt.

CONCLUSIONS

Federal Environmental Protection Agency water quality standards recommend that total phosphorus levels should not exceed 0.01 mg per liter in lakes and 0.10 mg per liter in rivers and that nitrogen levels should not be excess of ten times the phosphorus levels. At the present time all streams flowing into Hebgen Lake meet these criteria. However, levels of ortho-phosphorus are usually in excess of 0.01 mg per liter in the lake. Highest nitrate and ammonia levels were associated with the flooding of lake bottom exposed during drawdown. This was followed in July by an explosive growth of blue-green algae in the Grayling Arm. By the end of July practically all of the inorganic nitrogen supplies were used up while ample phosphate for phytoplankton growth still remained.

For these reasons it is my opinion that the relatively low levels of inorganic nitrogen compounds is the chief limiting factor for algal production in Hebgen Lake. Hebgen Lake because of warm summer temperatures, high chloride content and relatively high phosphate content is a suitable environment for blue-green algal growth. Two of the dominant species of blue-green algae are known to fix elemental nitrogen and can become independent of nitrogen in the form of nitrate and ammonia. It has been shown however that nitrogen-fixing blue-green algae will use nitrogen compounds preferentially before fixing elemental nitrogen. Thus any increase in the levels of ammonia and nitrate in the lake would tend to cause an increase in blue-green algae as well as other non-nitrogen-fixing species. With suitable disposal procedures (no sewage allowed to run into the lake) it can be predicted that the Ski Yellowstone development will not be detrimental to the lake.

Of the three major tributaries draining into Grayling Arm, Red Canyon Creek has the lowest recreation potential. The stream is extremely turbid during high runoff. At base flow levels the lower reaches below the highway bridge

possess a dense growth of filamentous algae. It also presents the greatest hazard for development because of the erodability of its water shed and the alluvial deposits at its lower reaches. While there is not much to be lost by increasing the silt load in the stream itself the important fact is that this stream is the greatest contributor to siltation of the lake. Therefore, every effort should be made to control erosion in the drainage area of Red Canyon Creek.

Both Grayling and Duck Creek are clear running streams. Within the area of interest fishing is largely confined to the vicinity of highway bridges or culverts over the two streams. Below the highways fishing access is difficult because of the dense growth of willows. However, because of the importance of the willow growth and swamps to wildlife and waterfowl nothing should be done to improve fishing access to this habitat.

Of the two streams Duck Creek is the most productive having both weed beds and good benthic growth. Brook trout in the stream itself and Brown and Rainbow at the mouth are the most important species. Although Grayling was once an important species in the stream this is no longer true since Grayling is an unsuccessful competitor with Rainbow Trout which was introduced into the stream.

Compared to other fishing waters such as the Madison River and Hebgen Lake these two streams are relatively unimportant and nothing should be done to improve the streams and access to them.

Table 1 Percentage Light Transmission

Depth	Date					
	May 18	June 4	June 15	June 26	July 6	July 26
Surface	100	100	100	100	100	100
1 meter	50	40	21	33	30	38
2 meter	32.5	11	17	27	14	23
3 meter	17.0	4	7	18	6	9
4 meter	10.0	0	4	7	4	4
5 meter	6.0		2	5	2	2
6 meter			0	3	0	0
7 meter				1		

Table 2 Turbidity Mg per liter SiO_2

Location	Date (1973)					
	May 18	June 4	June 15	June 26	July 6	July 25
Grayling Arm						
Surface		5	3	3	3	10
5 feet		12	3	1	1	5
10 feet		5	3	1	0	3
15 feet		5	3	1	0	3
20 feet		7	3	1	0	5
Red Canyon Creek						
Forest Boundary		20	15	1	1	3
Highway Culvert			15	1	3	0
Mouth		35	21	5	3	10
Duck Creek		10	5	1	1	5
Grayling Creek		7	5	0	3	0

Table 3 Temperature °C

Location	Date (1973)					
	May 18	June 4	June 15	June 26	July 6	July 25
Grayling Arm						
Surface	11.5	10.5	15.0	15.0	20.0	20.3
5 feet	11.0	10.0	15.0	15.0	19.0	19.7
10 feet	11.0	9.8	15.0	15.0	18.0	19.0
15 feet	11.0	9.5	14.5	15.0	18.0	18.2
20 feet	8.5	8.5	11.5	14.0	17.0	18.1
Red Canyon Creek						
Forest Boundary		2.5	11.0	9.2	13.5	7.8
Highway Bridge			11.0	14.5	15.5	10.8
Mouth		4.5	12.0	17.5	14.0	15.0
Duck Creek		7.5	14.0	17.0	14.0	14.9
Grayling Creek		5.5	8.0	12.2	14.0	9.0

Table 4 Oxygen Mg per liter

Location	Date (1973)					
	May 18	June 4	June 15	June 26	July 6	July 25
Grayling Arm						
Surface	9.90	9.00	8.76	9.00	8.90	8.60
5 feet	10.20	8.60	8.80	8.80	8.36	8.00
10 feet	10.20	9.00	8.80	8.70	8.40	8.40
15 feet	10.60	9.20	8.60	9.00	7.90	7.20
20 feet	10.30	8.20	7.40	8.00	7.40	6.80
Red Canyon Creek						
Forest Boundary		11.20	9.20	8.50	9.80	10.00
Highway Bridge			9.20	8.55	9.10	9.70
Mouth		11.20	9.20	8.50	8.82	9.20
Duck Creek		10.80	9.30	8.60	9.50	8.40
Grayling Creek		10.80	8.00	8.30	9.20	10.00

Table 5 pH

Location	Date					
	May 18	June 4	June 15	June 26	July 6	July 25
Grayling Arm						
Surface	8.60	8.05	7.60	8.20	8.82	8.55
5 feet	8.50	8.00	7.58	8.10	8.70	8.52
10 feet	8.38	7.90	8.02	8.00	8.40	8.60
15 feet	8.52	7.90	8.00	8.00	8.30	8.65
20 feet	8.40	7.85	7.85	8.20	8.30	8.60
Red Canyon Creek						
Forest Boundary		8.50	8.55	8.50	8.50	8.40
Highway Boundary			8.45	8.55	8.62	8.40
Mouth	8.50	8.60	8.50	8.50	8.65	8.45
Duck Creek		8.10	7.98	8.60	8.50	7.80
Grayling Creek		8.90	8.00	8.30	8.40	8.00

Table 6 Free Carbon Dioxide Mg CO_2 per liter

Location	Date (1973)					
	May 18	June 4	June 15	June 26	July 6	July 25
Grayling Arm						
Surface	0.30	0.73	2.98	0.56	0.19	0.38
5 feet	0.37	0.77	2.98	0.88	0.21	0.38
10 feet	0.52	1.07	1.22	1.33	0.49	0.31
15 feet	0.42	1.02	1.22	1.12	0.63	0.25
20 feet	0.50	1.63	1.80	0.71	0.67	0.29
Red Canyon Creek						
Forest Boundary		0.76	0.66	0.85	0.89	0.98
Highway Culvert			0.80	0.74	0.67	0.95
Mouth	1.13	0.60	0.74	0.81	0.51	0.81
Duck Creek		0.53	0.73	0.21	0.28	1.63
Grayling Creek		0.11	0.80	0.50	0.41	1.20

Table 7 Conductivity micro-mohos per cm x 10^{-6}

Location	Date (1973)					
	May 18	June 4	June 15	June 26	July 6	July 25
Grayling Arm						
Surface	132	92.	187	172	165	226
5 feet	160	95	201	172	162	194
10 feet	231	99	189	218	222	176
15 feet	231	84	203	194	224	176
20 feet	231	191	226	189	260	152
Red Canyon Creek						
Forest Boundary		397	443	636	790	940
Highway Culvert			440	634	720	980
Mouth		401	440	620	784	970
Duck Creek		65	78	100	121	108
Grayling Creek		86	88	108	122	128

Table 8 Total Hardness Mg per liter $CaCO_3$

Location	Date (1973)					
	May 18	June 4	June 15	June 26	July 6	July 25
Grayling Arm						
Surface	65.0	38.0	33.8	40.6	42.4	35.0
5 feet	57.2	38.0	32.4	37.6	40.0	37.2
10 feet	55.2	40.6	39.2	35.0	31.8	40.0
15 feet	31.2	42.4	31.2	33.4	31.8	43.8
20 feet	32.0	40.6	34.8	33.6	68.0	44.0
Red Canyon Creek						
Forest Boundary		213.0	310.0	350.0	437.0	554.8
Highway Culvert			228.0	336.0	428.0	523.0
Mouth	177.0	216.0	226.0	328.0	440.0	536.0
Duck Creek		27.8	26.6	33.0	38.0	38.0
Grayling Creek		38.8	39.8	50.0	56.0	58.4

Table 9 Calcium Hardness Mg per liter $CaCO_3$

Location	Date (1973)					
	May 18	June 4	June 15	June 26	July 6	July 25
Grayling Arm						
Surface	48.0	27.8	26.6	35.0	36.0	31.0
5 feet	42.0	27.0	23.2	27.6	28.0	30.0
10 feet	35.2	30.8	23.4	28.0	26.0	31.0
15 feet	23.2	33.0	24.4	28.0	25.0	34.5
20 feet	22.8	31.6	25.2	26.0	56.0	38.0
Red Canyon Creek						
Forest Boundary	143.0	163.0	178.0	263.0	344.0	466.0
Highway Culvert			178.2	272.0	349.0	437.0
Mouth		167.0	176.0	270.0	352.0	426.0
Duck Creek		18.0	21.4	37.0	30.4	30.0
Grayling Creek		30.0	31.2	27.0	45.6	44.0

Table 10 Total Alkalinity Mg per liter $CaCO_3$

Location	Date (1973)					
	May 18	June 4	June 15	June 26	July 6	July 25
Grayling Arm						
Surface	61.0	41.0	61.0	45.5	53.0	68.5
5 feet	61.0	40.5	61.0	55.5	58.5	62.8
10 feet	71.0	44.0	62.5	68.0	66.5	63.8
15 feet	69.0	42.0	62.5	57.5	64.5	57.5
20 feet	68.0	59.5	65.5	58.5	68.5	58.5
Red Canyon Creek						
Forest Boundary		125.0	119.5	138.5	145.5	134.5
Highway Culvert			119.5	134.5	138.0	130.0
Mouth	184.5	124.0	122.0	134.0	138.5	120.0
Duck Creek		33.5	37.5	43.5	46.0	53.5
Grayling Creek		44.5	41.0	51.5	56.5	61.5

Table 11 Calcium Mg per liter

Location	May 18	June 4	June 15	June 26	July 6	July 25
	Date (1973)					
Grayling Arm						
Surface	19.2	11.2	10.6	14.0	14.4	12.4
5 feet	16.8	10.8	9.2	11.0	11.2	12.0
10 feet	14.0	12.4	9.4	11.2	10.4	12.4
15 feet	9.2	13.2	9.8	11.2	10.0	13.6
20 feet	9.2	12.6	10.0	10.4	22.4	15.2
Red Canyon Creek						
Forest Boundary		65.2	71.2	105.2	137.6	186.4
Highway Culvert			71.2	108.8	139.6	174.8
Mouth	57.2	66.8	70.4	108.0	140.8	170.4
Duck Creek		7.2	8.6	10.8	12.2	12.0
Grayling Creek		12.0	12.4	14.8	18.2	17.6

Table 12 Magnesium Mg per liter

Location	May 18	June 4	June 15	June 26	July 6	July 25
	Date (1973)					
Grayling Arm						
Surface	4.1	2.4	1.8	1.4	1.6	1.0
5 feet	3.8	2.7	2.3	2.4	2.9	1.8
10 feet	2.4	2.3	2.6	1.7	1.4	2.2
15 feet	1.9	2.3	1.6	1.3	1.6	2.4
20 feet	2.2	2.2	2.4	1.8	2.9	1.5
Red Canyon Creek						
Forest Boundary		12.2	12.6	21.1	22.6	21.6
Highway Culvert			12.2	15.6	19.2	20.7
Mouth	8.3	11.9	12.3	14.1	21.4	26.8
Duck Creek		2.4	1.2	1.5	1.8	1.9
Grayling Creek		2.2	2.2	3.1	2.5	3.5

Table 13 Sodium Mg per liter

Location	Date (1973) May 18	June 4	June 15	June 26	July 6	July 25
Grayling Arm						
Surface	3.68	3.45	23.0	9.20	11.04	28.52
5 feet	9.89	3.45	25.99	17.48	17.02	21.62
10 feet	27.83	3.45	25.07	28.98	31.28	18.40
15 feet	34.96	4.14	29.21	21.16	32.66	12.88
20 feet	34.96	24.84	34.27	21.16	25.53	11.50
Red Canyon Creek						
Forest Boundary		4.60	5.52	7.59	11.04	11.50
Highway Culvert			5.29	7.36	11.04	12.42
Mouth	3.45	4.60	5.06	7.82	10.58	12.40
Duck Creek		3.68	3.91	4.83	5.98	5.52
Grayling Creek		1.84	1.27	1.84	1.84	2.30

Table 14 Potassium Mg per liter

Location	Date (1973) May 18	June 4	June 15	June 26	July 6	July 25
Grayling Arm						
Surface	1.27	0.96	2.91	1.56	1.56	3.13
5 feet	1.88	1.00	3.23	2.35	1.96	2.97
10 feet	3.87	0.92	3.05	3.32	3.32	2.58
15 feet	4.50	1.00	3.54	2.74	3.32	1.80
20 feet	4.40	3.15	3.91	2.54	2.93	1.80
Red Canyon Creek						
Forest Boundary		0.78	1.04	1.17	1.17	1.64
Highway Culvert			1.00	1.17	1.17	1.64
Mouth	1.06	0.84	1.00	1.17	1.37	2.19
Duck Creek		0.92	1.00	0.98	0.98	1.33
Grayling Creek		0.82	0.63	0.59	0.78	0.78

Table 15 Bicarbonate Mg Per liter

Location	Date (1973)					
	May 18	June 4	June 15	June 26	July 6	July 25
Grayling Arm						
Surface	74.4	50.0	74.4	55.5	64.7	83.6
5 feet	74.4	49.4	74.4	67.7	71.4	76.6
10 feet	86.6	53.7	76.3	83.0	81.1	77.8
15 feet	84.2	51.2	76.3	70.2	78.7	70.2
20 feet	83.0	72.6	79.9	71.4	83.6	71.4
Red Canyon Creek						
Forest Boundary		152.5	145.8	169.0	177.5	164.1
Highway Culvert			145.8	164.1	168.4	158.6
Mouth	225.1	151.3	148.8	163.5	169.0	146.4
Duck Creek		40.9	45.8	53.1	56.1	65.3
Grayling Creek		54.3	50.0	62.8	68.9	75.0

Table 16 Chloride Mg per liter

Location	Date (1973)					
	May 18	June 4	June 15	June 26	July 6	July 25
Grayling Arm						
Surface	1.65	1.35	15.20	5.0	6.50	15.70
5 feet	4.45	1.58	15.00	11.5	11.00	14.40
10 feet	17.40	1.50	15.15	19.0	15.50	11.95
15 feet	21.95	1.55	14.00	14.65	19.95	7.40
20 feet	22.05	13.75	17.0	14.85	15.55	7.45
Red Canyon Creek						
Forest Boundary		1.05	0.8	1.50	1.70	1.75
Highway Culvert			0.9	1.25	1.75	1.75
Mouth	1.50	0.85	1.0	1.25	1.25	2.00
Duck Creek		1.00	1.25	1.00	1.50	1.25
Grayling Creek		0.75	0.55	1.50	0.75	1.00

Table 17 Sulfate Mg per liter

Location	Date (1973)					
	May 18	June 4	June 15	June 26	July 6	July 25
Grayling Arm						
Surface	5.0	5.0	6.0	3.0	4.5	13.5
5 feet	7.0	4.0	6.0	6.5	6.0	7.0
10 feet	8.5	5.0	6.0	7.5	6.5	7.0
15 feet	7.0	6.5	6.5	5.0	6.0	6.0
20 feet	7.5	8.0	7.5	5.5	24.8	6.0
Red Canyon Creek						
Forest Boundary		87.0	112.5	230.0	315.0	430.0
Highway Culvert			115.0	190.0	259.7	400.1
Mouth	62.5	80.0	110.0	209.0	248.0	430.0
Duck Creek		5.0	5.0	3.0	7.5	6.0
Grayling Creek		5.5	3.5	3.0	3.0	4.5

Table 18 Fluoride Mg per liter

Location	Date (1973)					
	May 18	June 4	June 15	June 26	July 6	July 25
Grayling Arm						
Surface	0.45	0.45	2.06	1.00	1.70	2.40
5 feet	1.13	0.41	2.22	2.25	3.10	2.10
10 feet	3.20	0.41	2.43	3.45	5.65	1.35
15 feet	3.78	0.45	2.63	3.10	6.05	1.70
20 feet	3.78	2.38	3.08	2.95	4.20	2.25
Red Canyon Creek						
Forest Boundary		0.09	0.23	0.55	0.66	0.55
Highway Culvert			0.20	0.30	0.52	0.45
Mouth	0.23	0.23	0.16	0.45	0.90	0.45
Duck Creek		0.30	0.16	0.45	1.01	0.66
Grayling Creek		0.20	0.09	0.27	0.45	0.20

Table 19 Silica Mg per liter

Location	Date (1973)					
	May 18	June 4	June 15	June 26	July 6	July 25
Grayling Arm						
Surface	17.5	16.0	29.5	23.0	21.0	44.5
5 feet	22.5	16.5	35.0	35.0	26.5	40.0
10 feet	41.5	15.0	31.0	40.0	38.5	34.5
15 feet	45.0	16.0	36.0	30.0	36.5	26.0
20 feet	48.5	34.5	37.5	30.0	35.5	25.5
Red Canyon Creek						
Forest Boundary		14.0	7.0	9.2	8.0	10.0
Highway Culvert			7.5	9.0	9.0	10.0
Mouth	9.0	8.0	8.0	7.5	8.0	9.0
Duck Creek		22.0	22.0	20.5	27.5	30.0
Grayling Creek		7.5	11.5	12.0	15.0	15.5

Table 20 Ortho Phosphate Phosphorus Mg per liter P

Location	Date (1973)					
	May 18	June 4	June 15	June 26	July 6	July 25
Grayling Arm						
Surface	0.006	0.000	0.068	0.036	0.005	0.076
5 feet	0.010	0.005	0.084	0.040	0.020	0.068
10 feet	0.058	0.000	0.058	0.038	0.024	0.044
15 feet	0.024	0.005	0.058	0.030	0.036	0.024
20 feet	0.024	0.020	0.058	0.030	0.024	0.084
Red Canyon Creek						
Forest Boundary		0.010	0.000	0.010	0.005	0.024
Highway Culvert			0.000	0.005	0.005	0.024
Mouth	0.024	0.010	0.000	0.010	0.005	0.018
Duck Creek		0.005	0.010	0.010	0.020	0.038
Grayling Creek		0.005	0.000	0.018	0.005	0.018

Table 21 Ammonia Nitrogen Mg per liter N

Location	Date (1973)					
	May 18	June 4	June 15	June 26	July 6	July 25
Grayling Arm						
Surface	0.00	0.20	0.68	1.06	0.06	0.06
5 feet	0.00	0.30	0.96	0.66	0.06	0.00
10 feet	0.00	0.20	0.90	0.50	0.06	0.00
15 feet	0.00	0.20	0.45	0.20	0.06	0.00
20 feet	0.00	0.15	0.36	0.20	0.15	0.00
Red Canyon Creek						
Forest Boundary		0.00	0.00	0.15	0.02	0.00
Highway Bridge			0.10	0.00	0.02	0.00
Mouth	0.15	0.00	0.00	0.35	0.02	0.20
Duck Creek		0.15	0.15	0.15	0.30	0.15
Grayling Creek		0.00	0.00	0.15	0.06	0.00

Table 22 Nitrate Nitrogen Mg per liter N

Location	Date (1973)					
	May 18	June 4	June 15	June 26	July 6	July 25
Grayling Arm						
Surface	0.010	0.010	0.010	0.024	0.005	0.010
5 feet	0.010	0.032	0.032	0.024	0.014	0.010
10 feet	0.010	0.026	0.022	0.024	0.005	0.000
15 feet	0.010	0.026	0.016	0.020	0.014	0.000
20 feet	0.010	0.066	0.028	0.024	0.005	0.000
Red Canyon Creek						
Forest Boundary		0.030	0.022	0.000	0.032	0.024
Highway Culvert			0.030	0.000	0.014	0.024
Mouth	0.096	0.160	0.018	0.005	0.014	0.010
Duck Creek		0.030	0.024	0.000	0.042	0.010
Grayling Creek		0.060	0.010	0.000	0.014	0.024

Table 23 Chlorophyll A micrograms per liter

Location	Date (1973)					
	May 18	June 4	June 15	June 26	July 6	July 25
Grayling Arm						
Surface	3.41	5.74	8.77	5.13	19.87	42.59
5 feet	3.53	4.81	7.89	5.38	11.19	10.60
10 feet	5.73	5.00	8.79	3.04	5.33	15.75
15 feet	3.97	5.59	8.12	4.25	5.90	15.11
20 feet	5.29	5.45	7.69	5.33	14.87	11.12

Table 24 Chlorophyll A Mg per square meter

Red Canyon Creek	
Forest Boundary	0.16
Mouth	0.92
Duck Creek	0.24
Grayling Creek	0.16

Table 25 Surface Phytoplankton Volume Cubic millimeters per liter

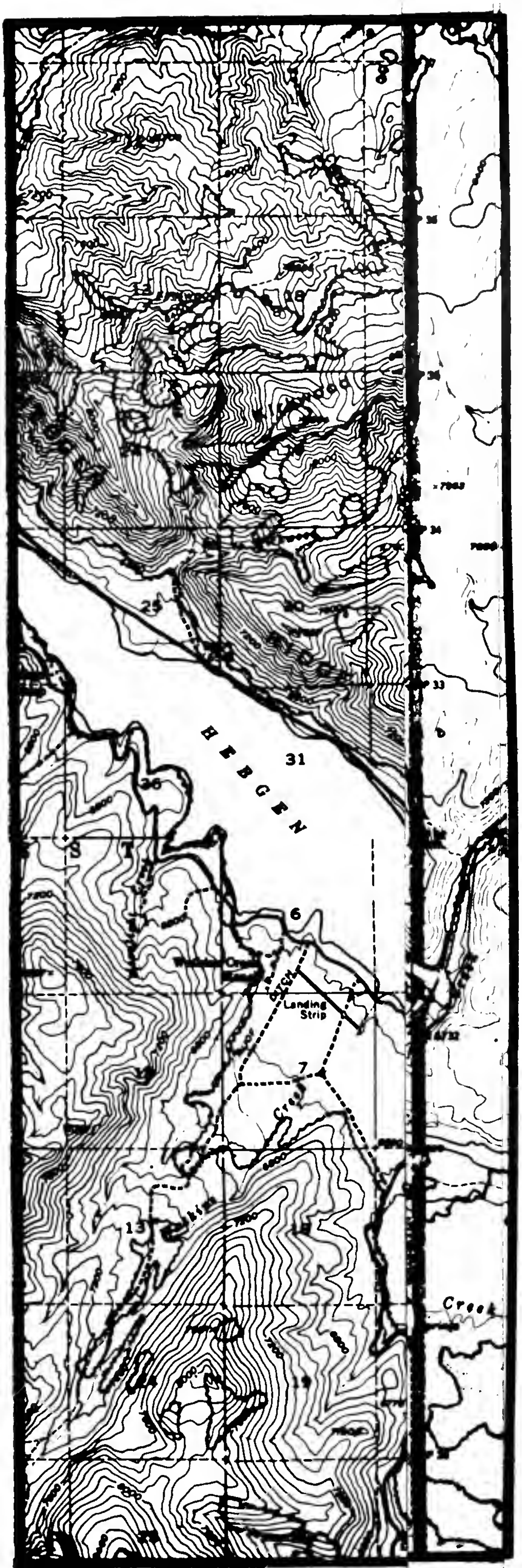
Species	May 18	June 4	June 15	June 26	July 6	July 25
	Date (1973)					
Asterionella formosa	0.06	0.10	0.01	0.09	0.10	0.01
Fragilaria crotonensis	0.12	0.07	0.01		0.23	0.32
Anabeana spiroides	0.02	0.08	0.01	0.02	1.06	2.55
Aphanizomenon flos-aqua				0.01		
Lyngbya birget						11.87
Total	0.20	0.25	0.03	0.12	1.39	14.75

Table 26 Zooplankton Number per liter

Species	May 18	June 4	June 15	June 26	July 6	July 25
	Date (1973)					
Daphnia galeata mendota	0.63	0.18	0.80		1.40	2.08
Daphnia schoedleri	0.63	0.17	2.04	0.12	5.50	1.25
Diaptomus nudus	1.26	.72	1.28			
Diaptomus leptopus					2.17	5.40
Cyclops bicuspidatus	0.31	1.76	5.44	0.29	18.00	3.60
Nauplii	1.57	2.11	3.68	0.08	3.33	1.80
Leptodora kindti			0.32			0.19

Table 27 Stream Insect Standing Crop Number per square foot Insect Group

Location	Mayfly	Midge Fly	Beetle	Caddis Fly
Red Canyon Creek				
Forest Boundary	15	15	1	
Mouth		4		
Duck Creek	9	25		
Grayling Creek	15	7		2



ENVIRONMENTAL SUMMARY
SECONDARY STUDY AREA

LIMNOLOGY

SAMPLING SITES

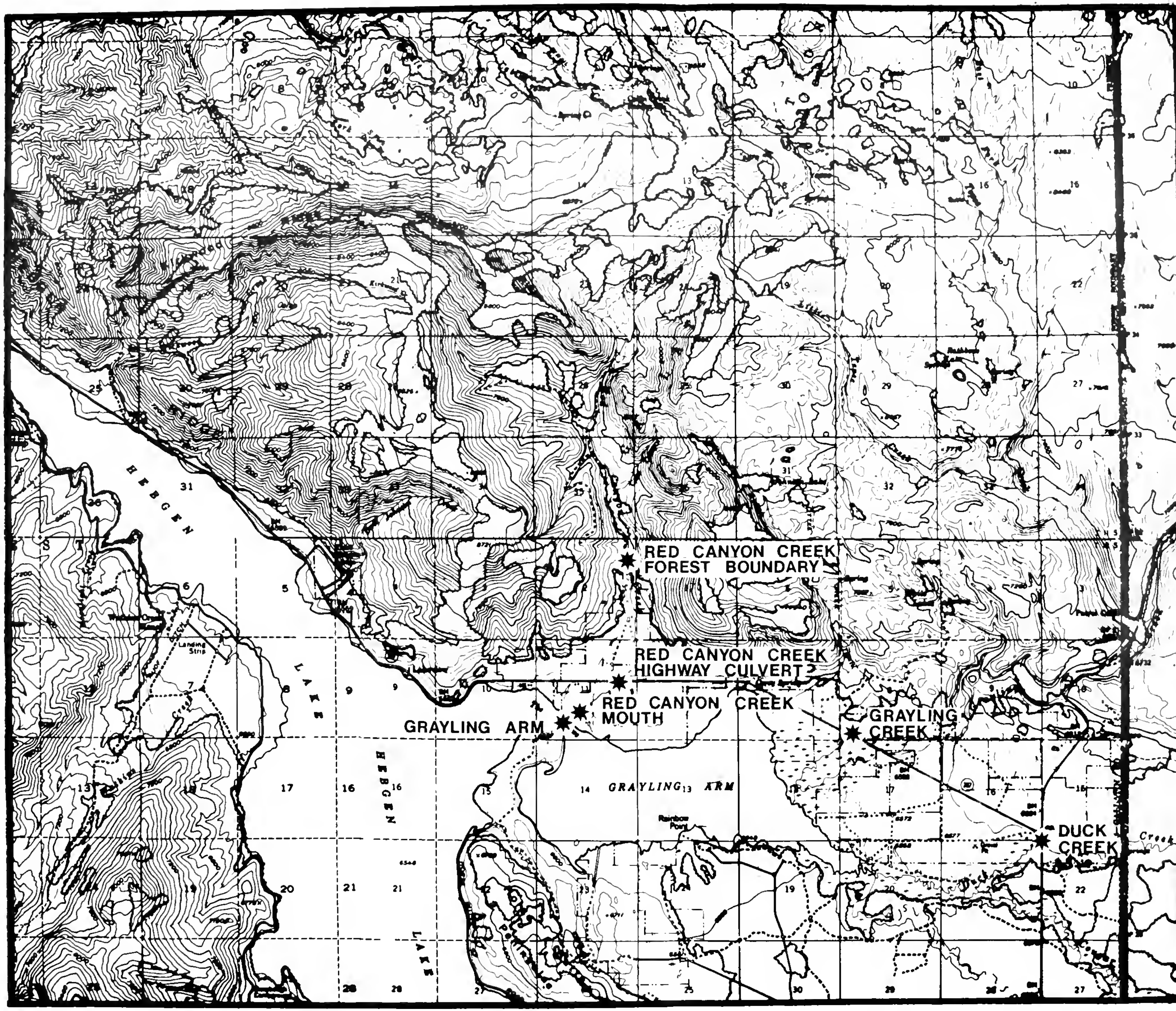
SKI YELLOWSTONE

SKI YELLOWSTONE INC.
WEST YELLOWSTONE, MONTANA

SCALE 1:62500

0 5000 10,000 FEET

0 1 2 MILES



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SURVEY OF SURFACE AND GROUND WATER QUALITY

J. J. Jezeski and Gary Bissonnette

INTRODUCTION

The water quality studies were performed to obtain a base line inventory of conditions for the following purposes:

1. To classify the various sites and sources according to the Montana water quality criteria and water use classification categories.

2. To determine suitability of wells, springs, and other sources as potable supples.

3. To establish if there are any evidences of pollution of any sort (natural or man-influenced) before construction or use.

4. To provide the base for any decision that the operation of the sewage disposal system or any other aspect of the project activities has (or has not) an impact on water quality.

Similar types of water quality studies have been conducted in other locations in Gallatin County, principally on various tributaries of the Gallatin River watershed, Mystic (Bozeman) Creek, Hyalite (Middle) Creek, Bridger Creek, West Fork, West and East Gallatin Rivers. The data have provided a base line inventory of water quality data in undeveloped semi-primitive forest areas, forested recreational areas (both limited access as well as open restricted) and in developed urban-suburban localities of open terrain as well as some indications as to the factors and critical activities which may affect water quality. The water quality studies in the Bridger Creek drainage provide information on the influences of a ski operation involving about 140,000 skier days in each of the past two seasons.

METHODS

Basically, the procedures included a physical examination (sanitary survey) of each sampling site and the surrounding areas which migh influence the quality of the sample. Water samples were subjected to microbiological and chemical analysis at intervals from June to August, 1973.

SAMPLING SITES

#2 Red Canyon Creek at forest boundary

#3 Red Canyon Creek - at fence south of small cabins

#4 Red Canyon Creek - at highway bridge

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SAMPLING SITES

#2 Red Canyon Creek at forest boundary

#3 Red Canyon Creek - at fence south of small cabins

#4 Red Canyon Creek - at highway bridge

#5 Red Canyon Creek - close to lake, just above the slack water zone

#6 Grayling Creek - just above highway bridge

#7 Duck Creek - at highway

#8 Hebgen Lake - Yellowstone Holiday - at entrance to lagoon near trailers

#9 Hebgen Lake - at mouth of Red Canyon Creek

#10 Hebgen Lake - Yellowstone Holiday - at entrance to Marina

LV Hebgen Lake - Lakewiew Resort - at entrance to marina

DJ Dave Johnson Creek - about 50 yards up into draw from old trailer park

SPR Spring on east facing mountain side to the west and above main cabin

HW1 Well at main cabin in Red Canyon

HW2 Well at mobile home at old Grayling community

MICROBIOLOGICAL PROCEDURES

Total coliform analyses were performed, utilizing the membrane filter technique with M-endo agar (Difco), adhering to procedures recommended in the 1971 edition of Standard Methods for the Examination of Water and Wastewater (1). Filter type HAWG - 047 - SO (millipore Corp.) with a pore size of 0.45 u was used. Plates were counted after 20-24 hr. incubation at 35 C. Confirmation of the presence of coliform organisms was obtained by picking a portion of coliform colonies on the Millipore filter to Brilliant Green-lactose-bile (BGLB) broth (Difco) for incubation at 35 C. Production of gas within 48 hr. was considered confirmatory evidence of the presence of a coliform organism.

Fecal coliform densities were determined by transferring a loopful of each of the previously mentioned BGLB broth cultures to EC broth (Difco). Production of gas within 24 hr. at 44.5 C was considered to be indicative of the presence of a coliform organism of fecal origin. In this way, probable fecal coliform densities could be calculated from the total coliform data.

CHEMICAL PROCEDURES

(1) Orthophosphate concentrations were determined by the direct colorimetric analysis procedures as recommended in Methods for Chemical Analysis of Water and Wastes (2).

(2) Ammonia concentrations were determined by the phenohypchlorite method of Solorzano (3).

(3) Nitrate concentrations were determined by the Mullin and Riley reduction method (4).

(4) Total hardness (EDTA titrimetric method), chloride (mercuric nitrate method), and sulfate (turbidimetric method) concentrations were all determined by adhering to procedures recommended in Standard Methods (1).

RESULTS

PHYSICAL INSPECTIONS

Stream sections (Red Canyon Creek)

1) From the point where the forest road forks down to the forest boundary (above sampling site #2) there was no evidence of contamination or abnormal conditions except for wildlife signs (deer and moose).

2) From the forest boundary to the fence south of lodge and cabins (above sampling site #3) - horses present with access to stream. No apparent evidence of any direct access of sewage effluent from lodge and cabins into the stream.

3) From fence south of cabins down to highway (above sampling site #4) - through 7/19/73, no cattle observed north of old Grayling community. Horse corral with 4 or more animals at creek west of building at old Grayling. Many swallow nests under highway bridge, underside almost completely covered with nests (most were occupied with birds). Many cattle were present on 8/18/73. They apparently had been moved from pasture south of the highway.

4) From highway to mouth of creek - slack water point (above sampling site #5). To 7/2/73, no animals observed, but there was some evidence of previous cattle occupancy. On 7/19/73, large numbers of cattle were observed in area but these were mostly scattered along the lakeshore. Fresh droppings were noted along the creek. No cattle were observed in this area on 8/18/73. They apparently had been moved out.

Lakeshore Sites

1) Red Canyon Creek area - from west property line on the lakeshore to the east property line. No evidence of pollution sources other than natural factors, wildlife and birds, up to 7/2/73. Large numbers of cattle along

shore on 7/19/73. These were absent on 8/18/73.

2) Yellowstone Holiday - No evident pollution sources at main marina. Could not determine locations of septic tanks and drainfields by inspection. Lagoon by trailer and mobile home settlement on west side of property shows evidence of higher nitrogen content. Substantial algae growths observed.

3) Lakeview Resort - Marina and adjacent areas exhibited no indications of evident pollution sources.

4) Hebgen Lake Lodge - along lakeshore no evidences of pollution sources except debris and other indications of camping activity. No toilet facilities available in this area.

Wells and Springs

1) Well at main cabin (sampling site HW#1) - no evidence of pollution source or any predisposing factors to contamination.

2) Well at mobile home in old Grayling settlement (at sampling site HW#2) - no survey inspection made.

3) Dave Johnson Creek (sampling site DJ) - This is essentially an uncovered, unprotected spring. Usual signs of wildlife observed. On 8/18/73, three deer were jumped in the creek bottom during the sampling. Heavy rank vegetation borders the stream bed.

4) Spring on east facing mountain side above and to the west of the main cabin (sampling site SPR). No survey made of the area. Fred Pack secured the sample.

ANALYTICAL RESULTS (Bacteriological, Chemical, and Physical)*

Red Canyon Creek Sites

1) Bacteriological - See Figure 1. Sites 2 and 3 showed coliform counts (both total and fecal types) typical of undeveloped areas where the principal sources are wildlife and indigenous flora. The water in the areas drained by these sample sites meets the bacteriological standards of Class A-Open, Montana Water Use Classification (5).

   Site 4 at the last sampling on 8/18/73 and Site 5 at the last two samplings on 7/19 and 8/18/73 reflect the large numbers of cattle having direct access to the stream. Based on both total coliform and fecal coliform

* For comparison on some sites, see also the data of Wright.

counts, the water drops in classification to a maximum of D_2. These high coliform counts remove it from the classification that permits primary contact recreational activity.

2) Chemical - See Figures 2 - 7. Sites 2, 3, 4 and 5 all produced water of great hardness and high sulfate content (Figures 2 and 3) and consequently very high conductivity (see Appendix tables). Nitrate contents are well below limits of concern as is the phosphate (Figures 4 and 5). The latter seems to be correlated postively with turbidity. The high sulfate is in excess of USPHS drinking water standards so on the basis of chemical analyses, these waters receive a C - D_2 classification.

Lake Sites (8, 9, 10, LV)

1) Bacteriological - See Figure 1. These four sites produced samples of very low coliform counts and conform to the B - D_1 classification of Madison River Waters.

2) Chemical - See Figures 2 - 7. These data reflect the differences in composition of Grayling Arm and Madison Arm waters and the extent of mixing by wind action. There is no evidence of any serious pollution sources. The higher ammonia content at the entrance to the lagoon by the trailer park at Yellowstone Holiday (site 8) may not be significant. Higher chloride on 8/18/73 at Site 9 is characteristic of Grayling Arm water.

Well and Spring Sites (HW1, HW2, DJ, SPR)

1) Bacteriological - See Figure 1.

No evidence of pollution based on microbiological tests - coliform counts were very low on DJ, none were detected in the wells and Site SPR. Results on DJ are typical of an open, unprotected spring (wildlife plus indigenous flora).

2) Chemical - See Figures 2 - 7.

These data indicate HW1 and HW2 are similar to Red Canyon Creek water, namely: high sulfate and extremely hard. DJ and SPR are low in sulfate. DJ is typical of water exposed to decaying vegetation, high in NH_3. All four sites produced waters somewhat higher in nitrate than the other sites, but the values do not approach those of concern.

Grayling and Duck Creeks (6 and 7)

Show bacteriological and chemical results typical of undeveloped, semi-primitive areas. They possess the characteristics of A-Open Waters.

SIGNIFICANT FINDINGS

1. The two Wells (HW1 and HW2) are unsuitable for development as potable water supplies because sulfate contents exceed the USPHS drinking water standards. DJ and SPR are satisfactory in all characteristics.

2. Cattle grazing on the alluvial fan imposes a pollution burden on Red Canyon Creek, rendering it unsuitable for primary contact recreation uses.

3. No evident sources of pollution were observed along the lakeshore. Water quality at all sites tested was suitable for primary contact recreational activity.

4. High turbidity and sediment loads were observed on Red Canyon Creek during high water periods (to 7/2/73).

PREDICTED IMPACTS

1. Elimination of cattle from pastures on Red Canyon Creek will result in improved water quality (reduced coliform counts) on this stream.

2. There will be a deterioration in water quality during construction, and this will persist for a short time thereafter (high turbidity and sediment).

3. With appropriate sewage treatment facilities and performances, there will be no real change in ground water or surface water characteristics (6).

4. The skiing activity itself (skiers on the slopes) will not have an impact on water quality (based on Bridger Bowl data).

5. Sanitary hazards may result from inadequate control of boat toilet facilities and practices.

SUGGESTED COUNTER-MEASURES

1. Avoid building marina or public boating facilities at mouth of Red Canyon Creek.

2. Construct one or more settling ponds at Red Canyon Creek during construction period and for a year thereafter. To avoid harmful flushing action as the ponds are drained, ponds should be constructed according to the most feasible hydrologic arrangement.

3. Provide adequate toilet dumping stations at marina.

REFERENCES

1. American Public Health Association. 1971. Standard Methods for the Examination of Water and Wastewater. 13th Ed., A.P.H.A., New York, 769 pp.

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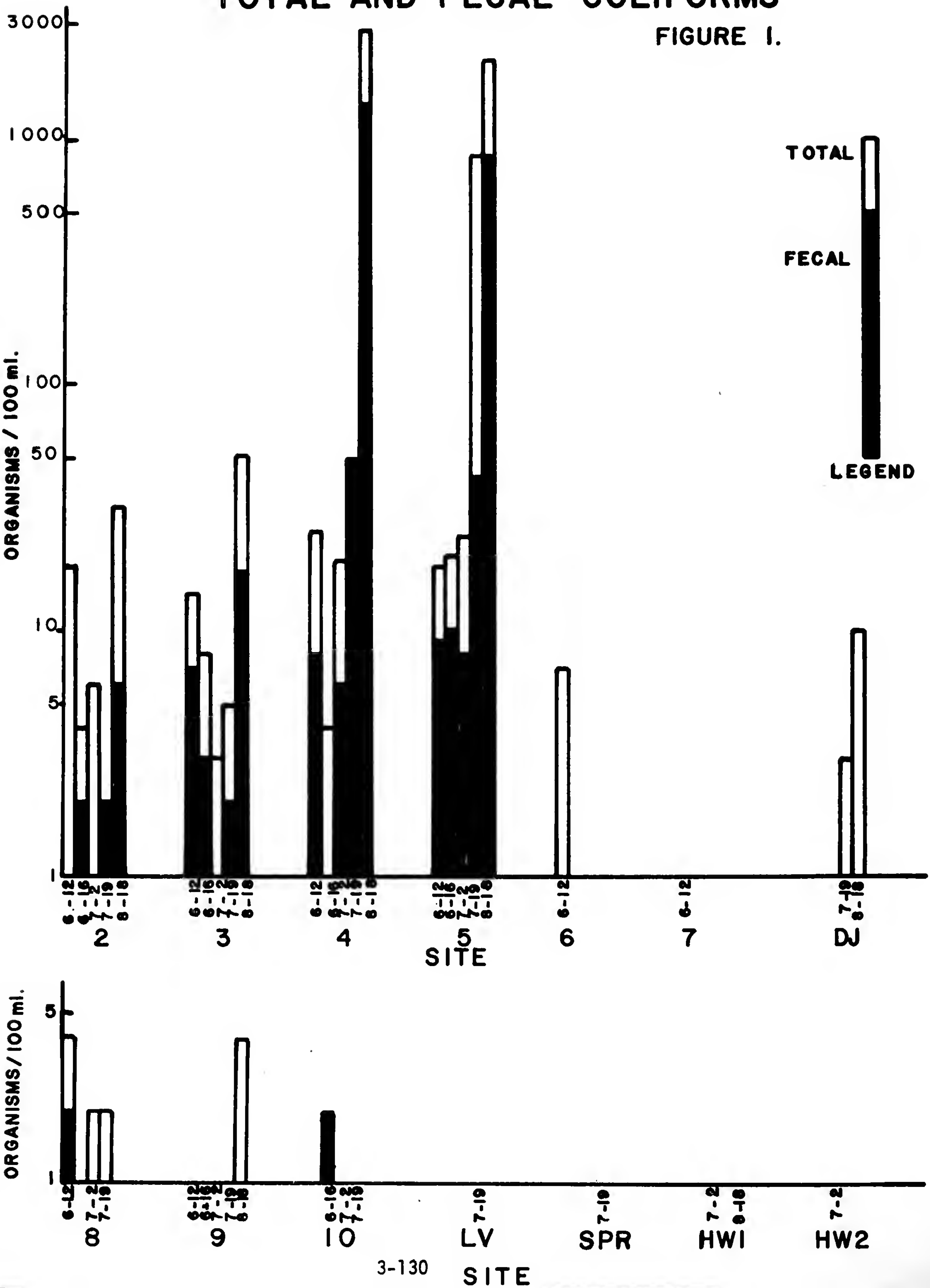
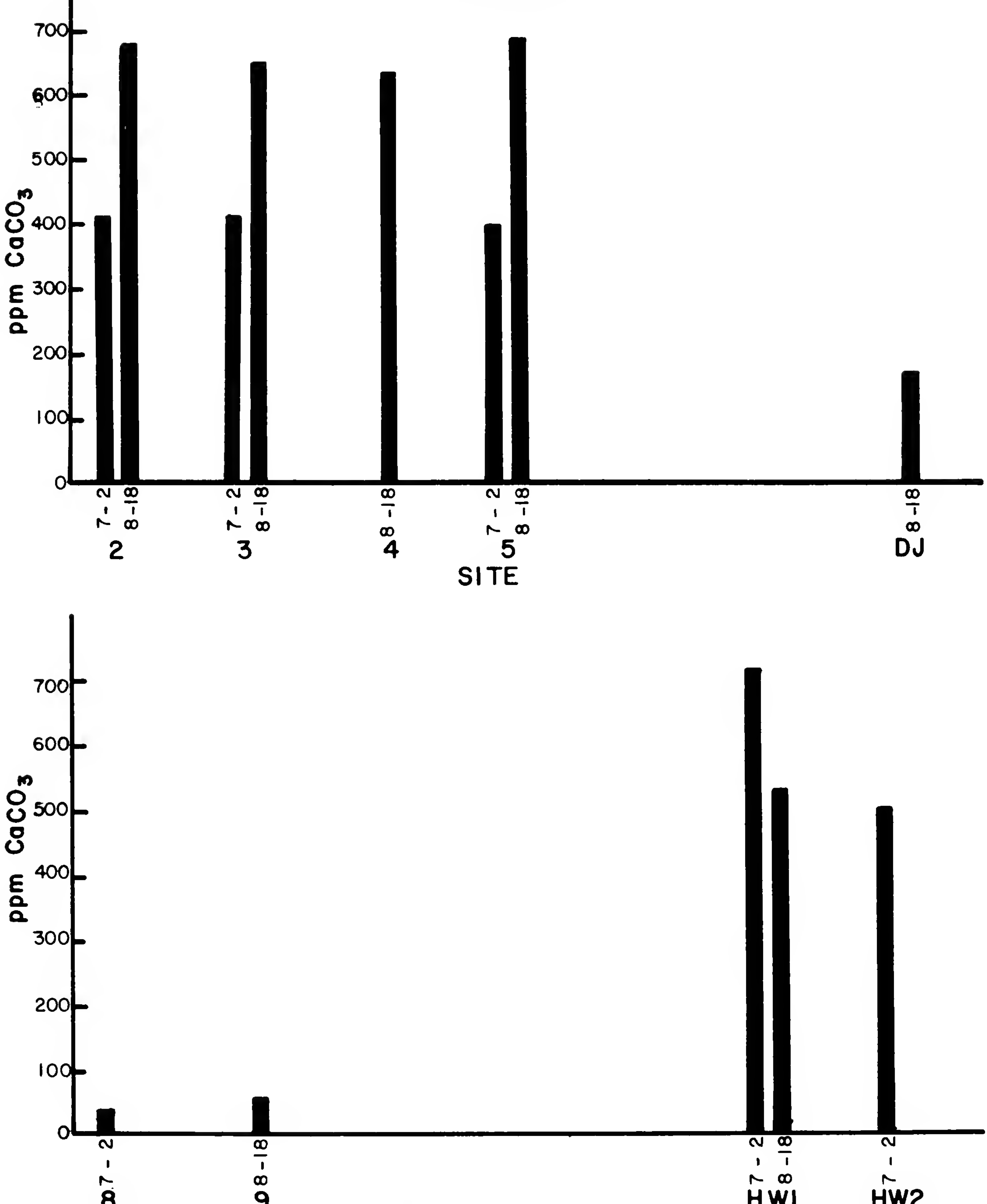
TOTAL AND FECAL COLIFORMS

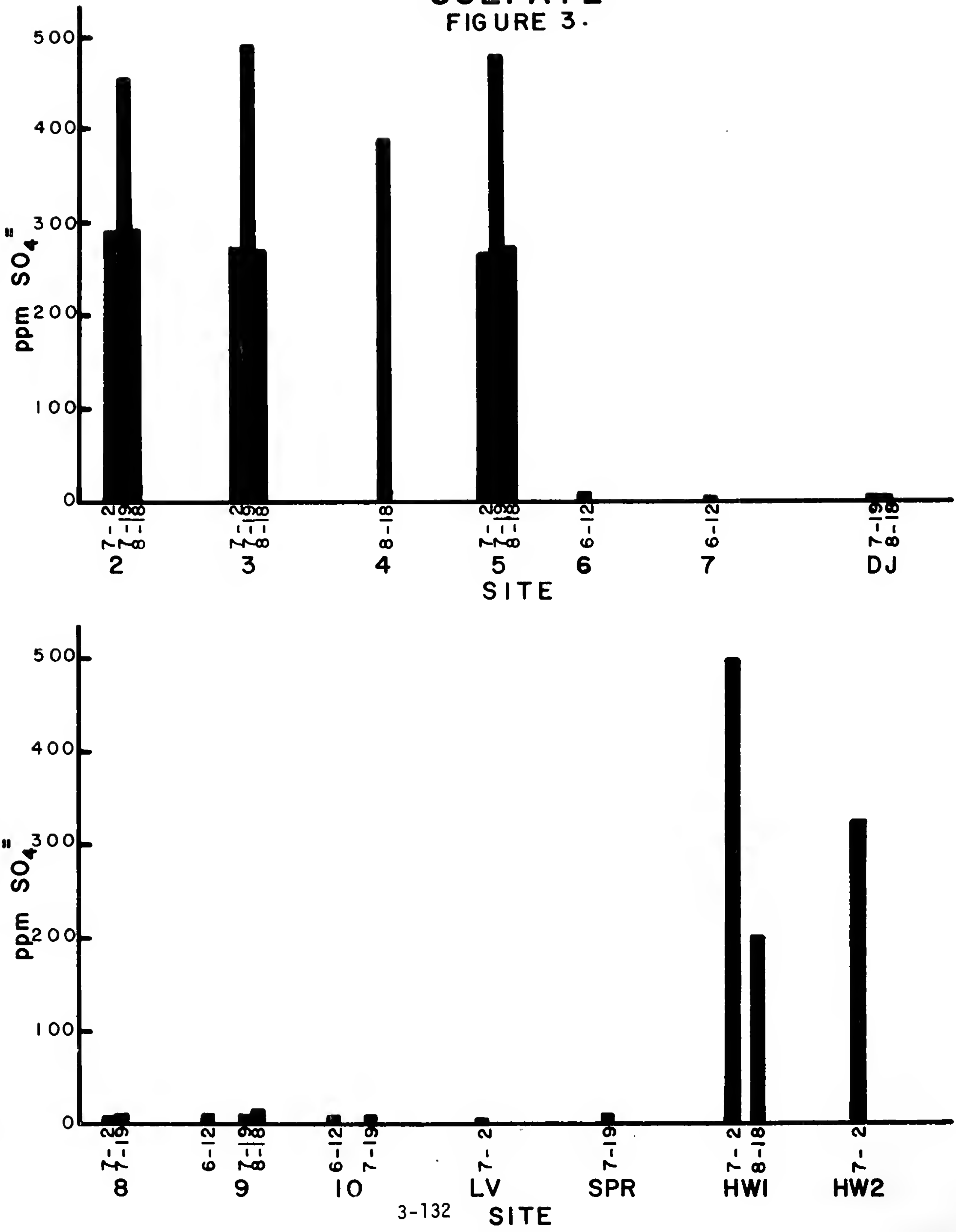
FIGURE I.



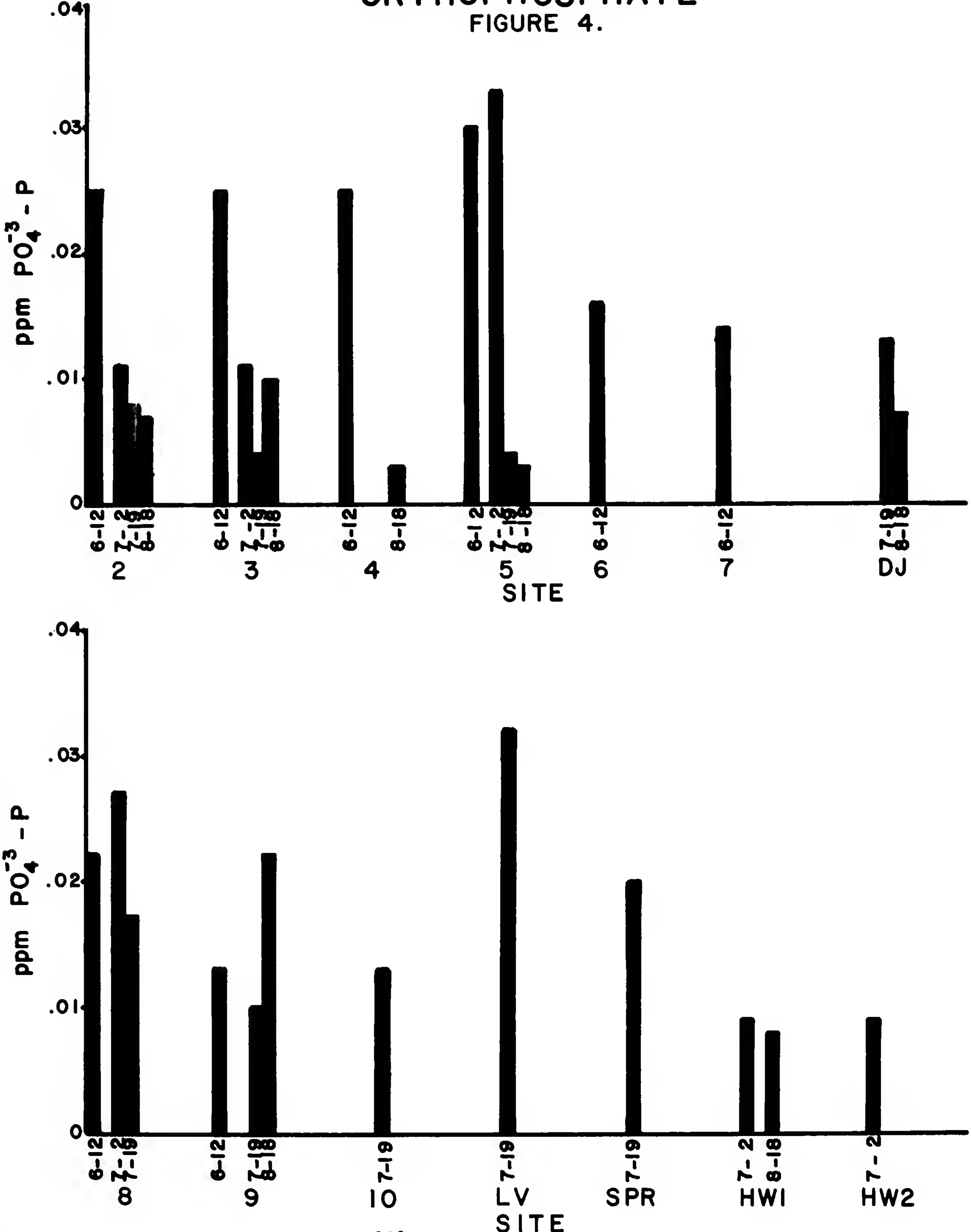
TOTAL HARDNESS
FIGURE 2.

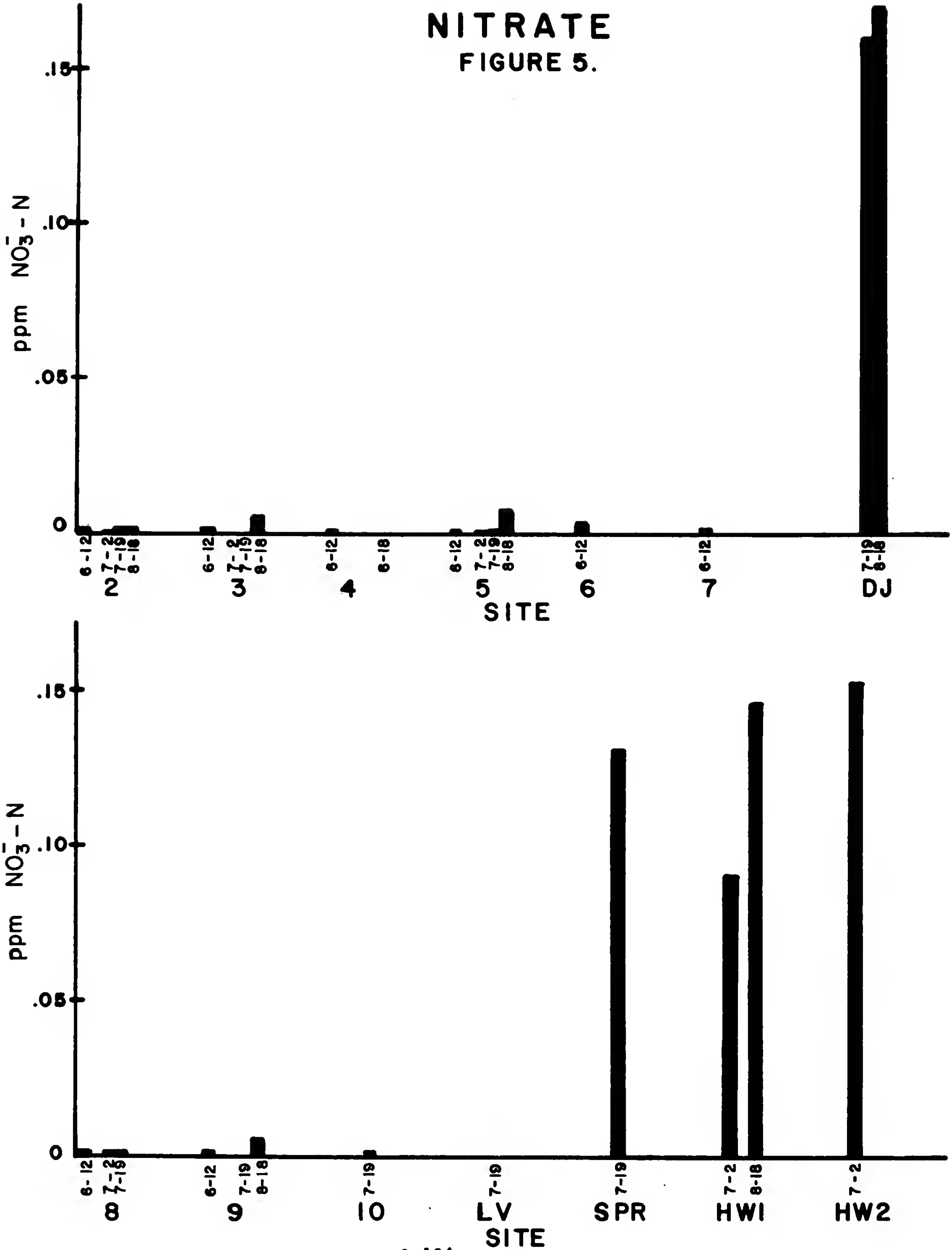


SULFATE
FIGURE 3.

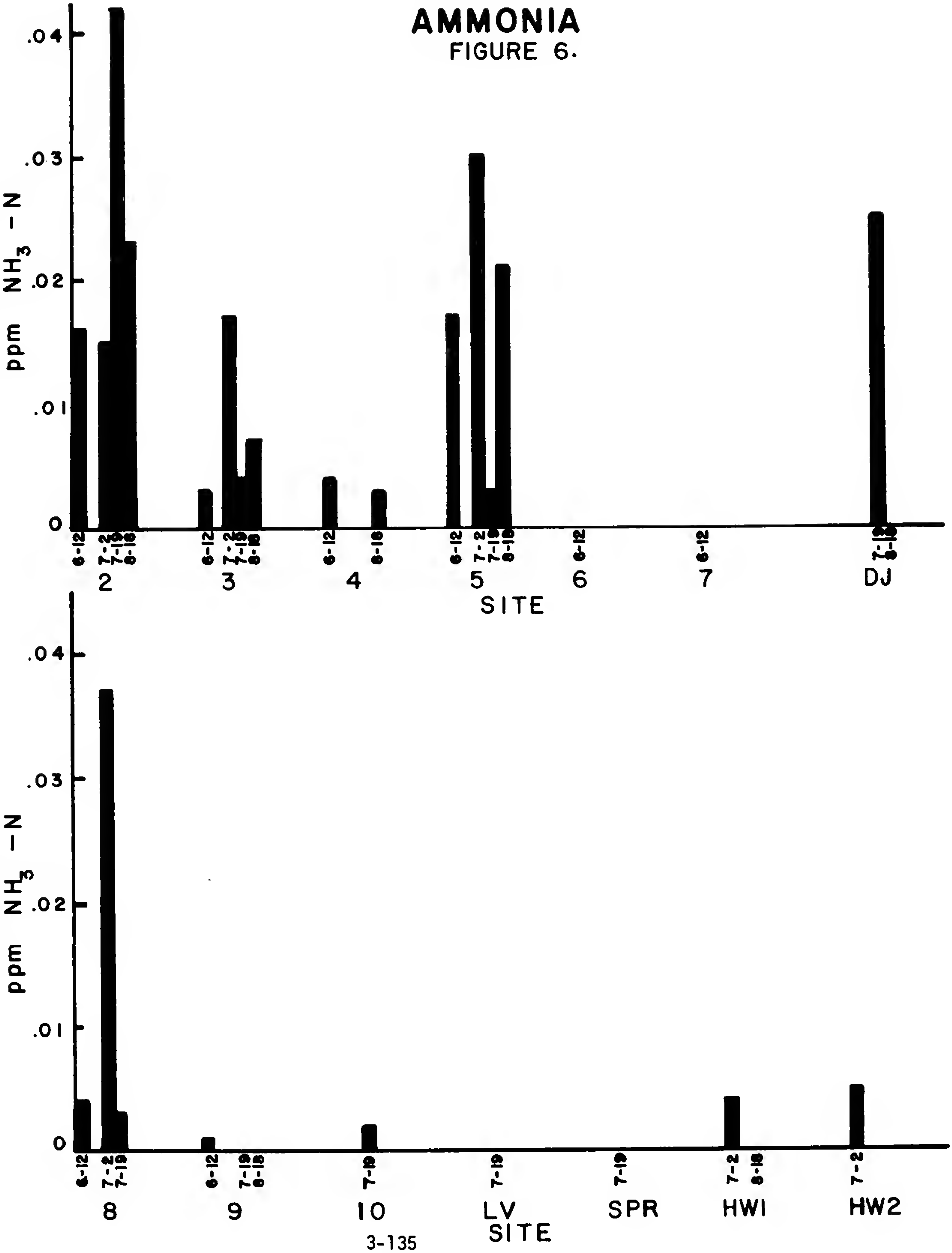


ORTHOPHOSPHATE
FIGURE 4.





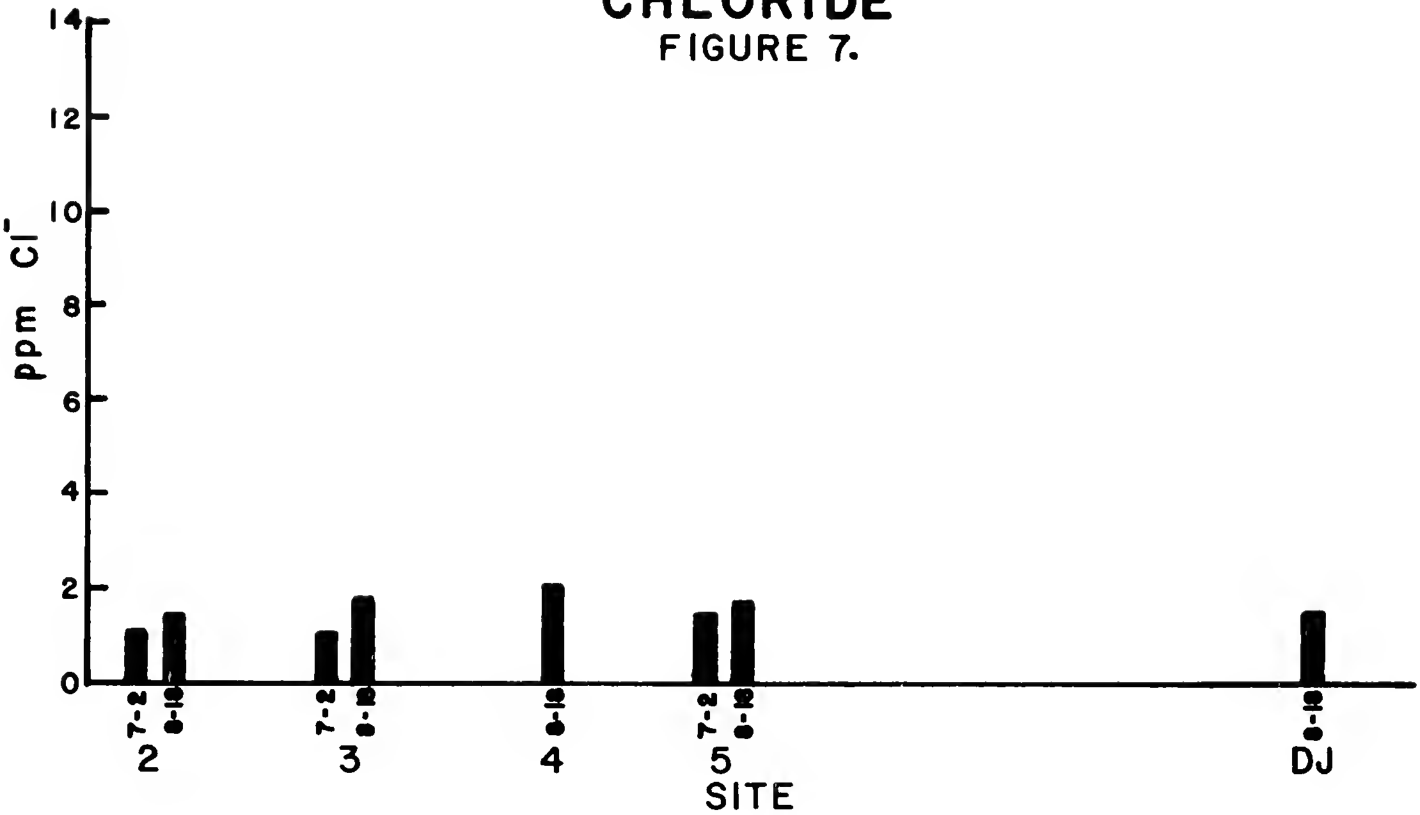
NITRATE
FIGURE 5.

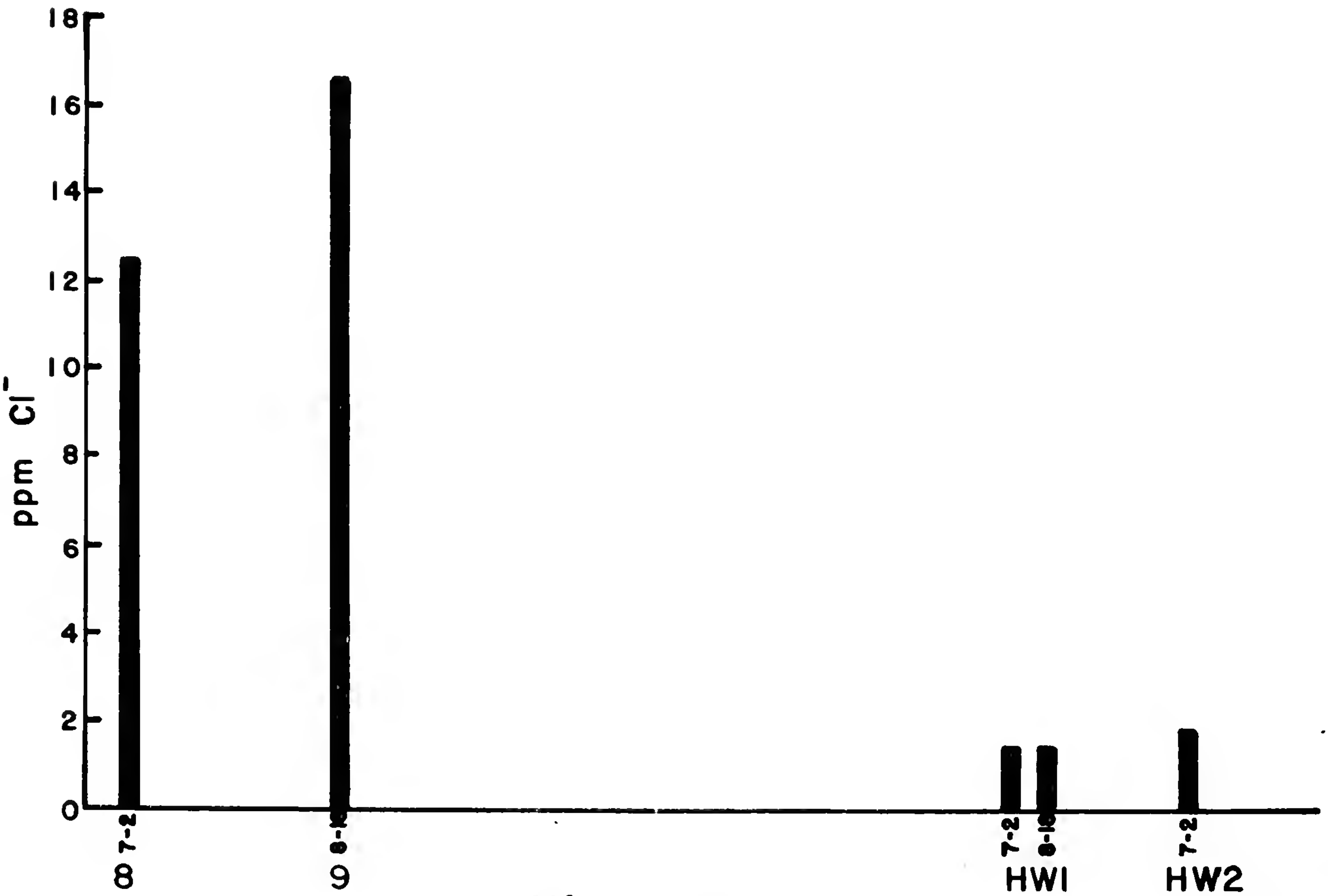


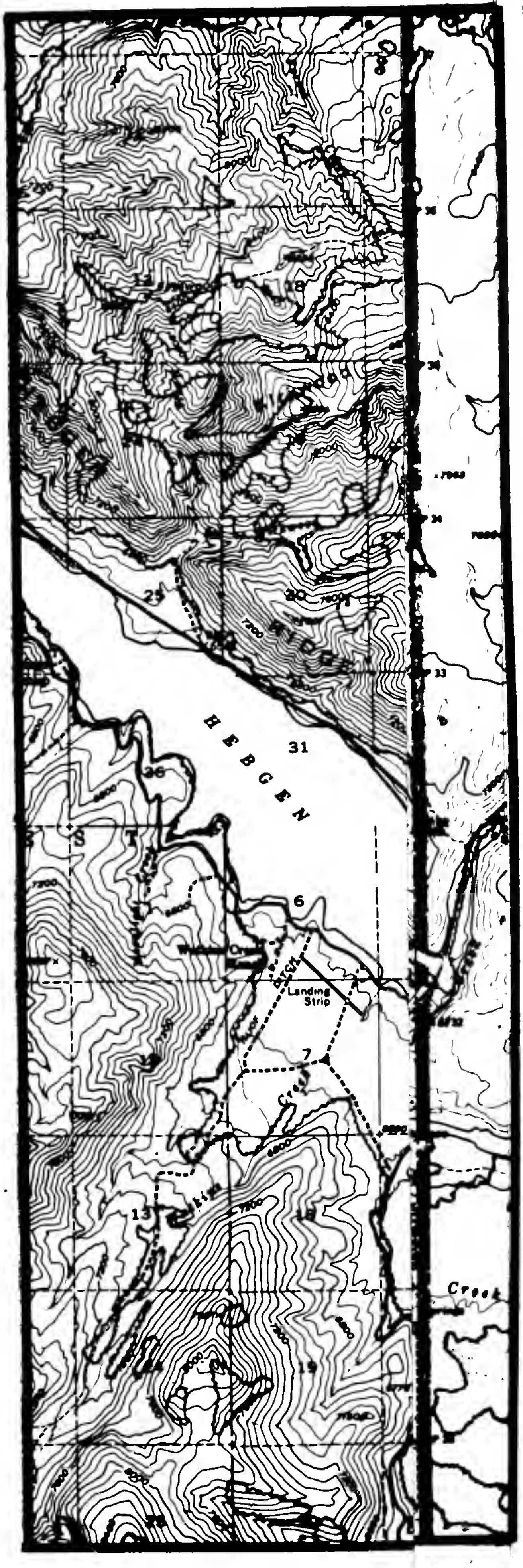
AMMONIA
FIGURE 6.
ppm NH_3 – N
.04
.03
.02
.01
0
2
3
4
5
6
7
DJ
SITE
8
9
10
LV
SPR
HWI
HW2
SITE

CHLORIDE

FIGURE 7.







ENVIRONMENTAL SUMMARY
SECONDARY STUDY AREA

WATER QUALITY

SAMPLING SITES

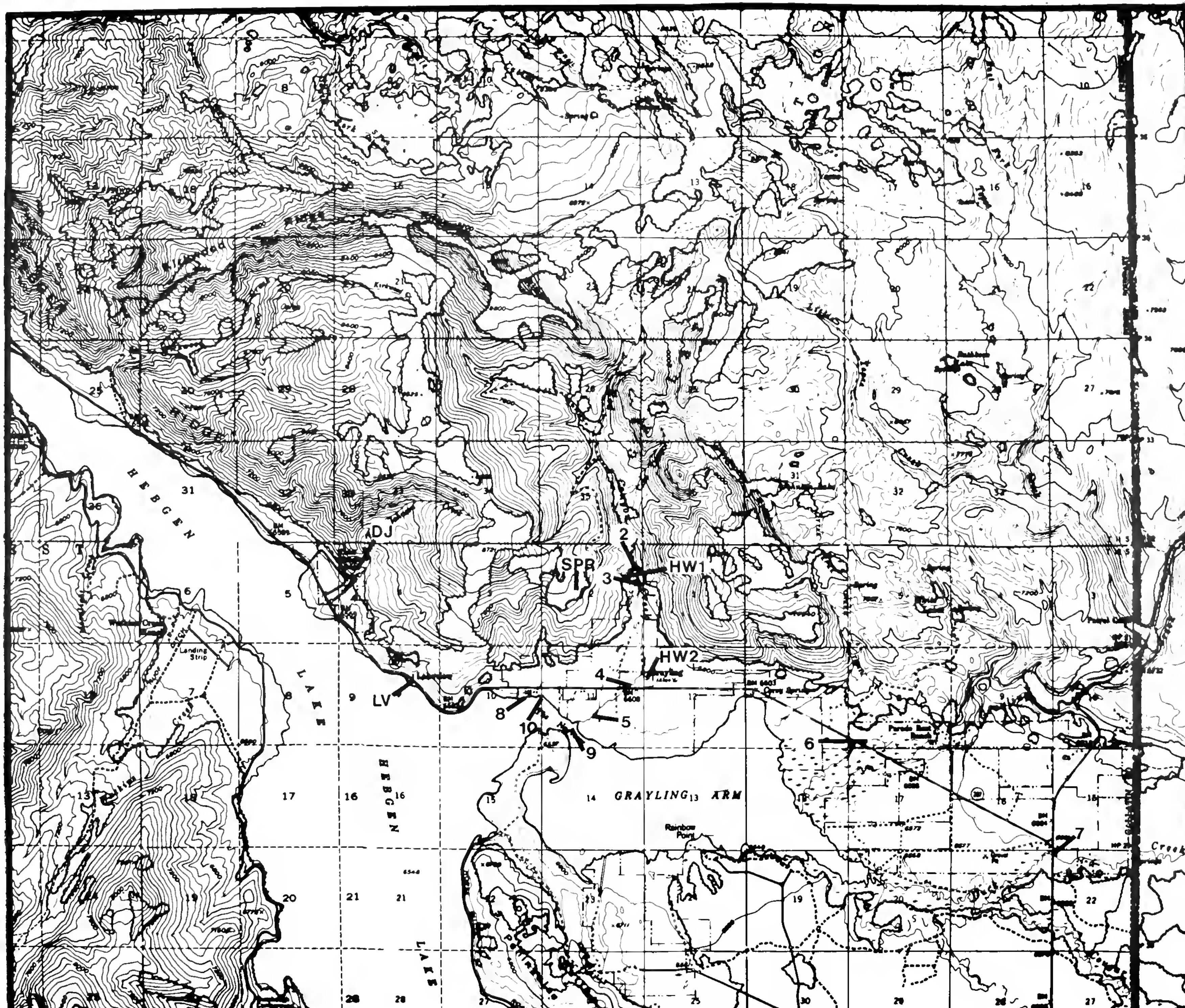
SKI YELLOWSTONE

SKI YELLOWSTONE INC.
WEST YELLOWSTONE, MONTANA

SCALE 1:62500

0 5000 10,000 FEET

0 1 2 MILES



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PLANT ECOLOGY
Brent M. Haglund

INTRODUCTION

Plant communities in the vicinity of the proposed ski resort-land development, Ski Yellowstone, were studied in spring and summer, 1973. The studies, made for planning and environmental impact assessment purposes, emphasized the following considerations: vegetation mapping to establish spatial distribution of vegetation types, relationship of existing communities to the environment, presence of rare or unique communities, and response and suitability of various communities to development and use related disturbances.

Vegetation studies were restricted to the primary study area. This is located about one mile eastward and one mile westward of Red Canyon Creek. The northern boundary was Kirkwood Ridge and the southern, Hebgen Lake. This is within the borders of the Hebgen Ranger District, Gallatin National Forest and near West Yellowstone, Montana.

The area's vegetation pattern is a complex of types ranging from forest to grassland. All of them are dependent upon the interrelationship of environmental factors such as moisture, sunlight, soil type, and disturbance events, i.e., fire, logging, or grazing (Patten, 1963). For this study a vegetation type is considered to be an identifiable unit with a recognizable border. Most of the vegetation types are found in several places on the site. Each separate location is termed a community. Some of the low altitude vegetation types have been greatly altered by cultivation or development. Some timber stands have been logged. But most of the area's vegetation types exist at present because of natural, not man-caused, processes.

Study of the vegetation is important to the overall study because it is a base for diverse animal communities, provides certain commodities, adds beauty to the landscape, and controls degradative processes such as erosion. A number of local studies provided a reference background for this planning analysis (Dale 1973; Patten 1963; and others). Regional studies, especially Daubenmire and Daubenmire (1968) and Daubenmire (1970), aided in description and clarification of the existing vegetation types.

METHODS

Analysis of U. S. Forest Service aerial photographs, both color and black & white, was central to the vegetation mapping effort. Black & white photos were of the EIO series (1962), and color photos were of the EXX series (1971). Photo scale was 1:15840. Communities were differentiated on the photos, and then field reconnaissance was made of all large communities and most smaller ones. U. S. Forest Service timber type maps (1957) were used when possible.

Field reconnaissance entailed recording of: overstory vegetation; invading potential overstory vegetation, if any; five most abundant species in cover

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Field reconnaissance entailed recording of: overstory vegetation; invading potential overstory vegetation, if any; five most abundant species in cover

value; and all species present. Vegetation clumping and other characteristics of distribution were noted. Stands were covered on foot in linear transects. Notes were taken of: amount of bare ground; surface rock, if present; disturbance evidence; elevation; exposure direction (aspect); degree of slope; and depth of soil.

Species nomenclature follows Booth (1950) and Booth and Wright (1959). Community nomenclature follows Daubenmire and Daubenmire (1968) and Daubenmire (1970) whenever possible.

RESULTS

The vegetation map indicates the areal extent and distribution of the primary study area's twenty-one vegetation types. Some are climax vegetation types, that is they will reproduce and perpetuate themselves if not disturbed. Others are transitory and reflect past disturbance, mostly within the historical past. Examples are the clear-cut areas with their snowberry and fireweed and burned sites which may now be lodgepole pine stands.

The map and this report are organized primarily by vegetation structure, e.g., coniferous forest and, secondarily, by characteristic species, e.g., Douglas fir-Snowberry. Parentheses indicate invading species which will eventually dominate the site. For each type the taller species is listed first and then the characteristic shorter, less conspicuous species follow. This report is ordered sequentially in the same manner as the legend.

The most conspicuous and abundant structural unit is the coniferous forest which includes Douglas fir, subalpine fir, Engelmann spruce, lodgepole pine, and whitebark pine trees in the overstory. Then follow shrub-grassland types, grassland types, deciduous forest (aspen stands), types, shrub types, rush-sedge types, and finally the forb types, which are least abundant. Douglas fir forest stands are predominant on the site and include three variations. The smallest mappable types are the two forb dominated vegetation types which consist of one community each..

Each vegetation type will be discussed in the following manner: characteristic species and a few other common species, general location in the study area, dynamics of the vegetation, commonness of the type, and considerations of hazards and suitability for use. These factors, plus a comprehensive species list for each type, will be summarized in tabular form in the appendix.

CONIFEROUS FOREST

Douglas fir-Snowberry. This is perhaps the single most common vegetation type on the primary study area. The Douglas fir trees range in size from seedlings to mature trees greater than 20 inches d.b.h. (diameter breast height). This indicates a climax vegetation reproducing itself. The understory is a mixture of low shrubs, forbs, grasses, and sedges. Snowberry is most often one to three

feet tall. Buffaloberry is sometimes taller but not common in this type. Juniper forms low mats. Five most common species are Douglas fir, snowberry, meadow rue, Arnica cordifolia, and white spiraea.

If cleared a snowberry-fireweed association will develop. Ski slope maintenance will prevent the reemergence of tall shrubs or trees. Low hazard for use, except on steep shallow soiled places. Then care should be exercised during construction to avoid vegetation loss.

Douglas fir-(Subalpine fir)-Snowberry. Found on north slopes and the subalpine fir is invading and will eventually dominate. Douglas fir became established following a disturbance such as fire. Eventually grouse whortleberry will be the dominant understory plant. At present Douglas fir, subalpine fir, snowberry, meadow rue, and bracted pedicularis dominate the type. Low hazard for use.

Douglas fir-Whitebark Pine-Balsamroot. Found on high altitude southerly slopes. Ground cover is low with thin soils and exposed rock rubble. This type is often on very steep slopes. Besides the identifying species big sagebrush and blue flax are most common. This has a high hazard for manipulation and ski slope development is not recommended. Serves as escape cover and foraging area for wintering elk.

Subalpine fir-Grouse Whortleberry. Without recent fires would be much more common. Found at varying elevations and most exposures except southerly on the site. Arnica Cordifolia, glacier lily, and Engelmann spruce were commonly found in these stands. This is a climax vegetation type. A low hazard area if care is taken during clearing of the trees for runs and lifts.

Subalpine fir-Whitebark Pine-Grouse Whortleberry. In this high altitude type the subalpine fir and whitebark pine are both climax trees but the fir is usually more common. Grouse whortleberry, Pyrola secunda, and glacier lily are most common in the understory. Not often found on steep slopes so development hazard is low. If pedestrian traffic is proposed in this type trails should be built. Receives year-round blue grouse use.

Engelmann Spruce-Grouse Whortleberry. This type is restricted to moist pockets where cold air settles and shading is extreme from adjacent slopes. Pyrola secunda, mosses and lichens, and Arnica latifolia are also common on the sparsely covered forest floor. Subalpine fir reproduction occurs occasionally. Hazard for development is moderate as the spruce has poor ability to reseed and surface water flow may occur.

Engelmann Spruce-Willow. This is found in drainage areas with actively running water. Buffaloberry, juniper, and a variety of forbs make up the understory. This type lines Red Canyon Creek in the canyon, but where the canyon effect is lost the spruce is no longer found. Hazard for development is moderate to severe because of moose foraging on the willows during winter and this type's function in stream bank control.

DECIDUOUS FOREST

Aspen. This deep soil vegetation type is found on moist areas around the mouth of Red Canyon Creek and on land slides and slumps. Vegetation is variable but usually is very abundant under the aspen overstory. Common are: Kentucky blue grass, sticky geranium, snowberry and young Douglas fir seedlings. Development hazard is moderate to severe because of its presence on areas with a high potential for slides and its use as a moose and elk wintering area.

SHRUB COMMUNITY

Big Sagebrush-snowberry. This is located in one location just below the top of Mt. Hebgen and may have supported Douglas fir trees before a fire occurred. The shrubs are dense but patchy. Consequently, ground cover is low. Associated species are: mountain brome, balsamroot, and occassionaly Douglas fir trees. Rock rubble is abundant near the surface. Hazard is moderate, and care should be exercised if mowing of shrubs takes place.

Willow. This is found along the Red Canyon Creek and several species of willow find abundant water here. They include: Salix drummondiana, Salix myrtillifolia, and Salix geyeri. Woods rose, shrubby cinquefoil, and big sagebrush also are associated a bit further from the water. Development hazard is high and should avoid this zone at the risk of accelerating bank sloughing. Willows will invade the unused stream channel on the alluvial fan if water is diverted into it. In anticipation of this willows might be planted in the intended stream bottom to reduce erosion.

SHRUB-GRASSLANDS

Big sagebrush-Idaho fescue. This type is found at most elevations on the area but usually on only moderately exposed slopes. Associated species include: sticky geranium, northwest cinquefoil, and sulfur eriogonum. A good deal of the village development will occur on this type. Kentucky blue grass is an invader in this type which bodes well for lawns that are likely to spring up following obliteration of this. Development hazard is low.

Big sagebrush-Hoary Sagebrush-Idaho Fescue. This moister site variant of the preceding type composes another good part of the village site. A large Uinta ground squirrel population resides here. Sticky geranium and northwest cinquefoil are still abundant. The hoary sagebrush is present perhaps because of ground squirrel or grazing disturbance (Patten 1968). This will also support lawns. Development hazard is low.

Big Sagebrush-Wheatgrass. Idaho fescue is conspicuously absent from this type which provides most of the forage for the area's wintering elk. It dominates the arid south facing slopes. Balsamroot, silver leaf phacelia and sulfur eriogonum are common. Development hazard is severe for most of this type because of the associated wintering elk. Also revegetation will be difficult if the type is disturbed.

Big Sagebrush-Balsamroot. This is a very dry type with low values of plant cover. It is found on rock outcrops and shallow soil colluvium slopes. Blue flax, snowberry, and juniper are usually associated. Openings in the Douglas fir-Whitebark pine-Balsamroot vegetation type are most often composed of this. Development hazard is severe because revegetation potential is low and most occurrences are steep, in some cases cliffs where the vegetation occurs in cracks.

Snowberry-(Douglas fir)-Fireweed. This is restricted to the four recent clear cuts of the area. Vegetation is in the early successional stages, is very diverse and dense. Carex geyeri and musk mallow are, also, common but this type is difficult to characterize because of the diversity of species. In the clear cut area east of Red Canyon Creek lodgepole pine seedlings are present in lieu of Douglas fir. This is a very dynamic type which will soon become forest. Much logging slash will have to be cleared before this type is ready for intensive skiing. Development hazard is low.

GRASSLAND

Bluegrass-Timothy-Smooth brome. These three grasses are present where the native sod was broken and these planted. Basically this area is the eastern portion of the Red Canyon Creek alluvial fan. Alfalfa and dandelion are common in this cultural vegetation type. Productivity is high, but plant diversity is low relative to a natural vegetation type on those sites. This type has been plowed in portions as recently as 1970 and is cropped by grazing or mowing for hay. Development hazard is low although some waterfowl nesting takes place in it. It is well suited for sprinkler irrigation or lawn plantings.

Idaho fescue. The mountain grasslands of deep soil and gentle slope are dominated by this bunchgrass. Often it is separated from the Big sagebrush-Idaho fescue type by only several inches greater depth to bedrock. Common associated species include: northwest cinquefoil, silky lupine, mountain dandelion, sticky geranium, and several species of grasses and sedge. Development hazard is low, and Kentucky blue grass seeding is recommended for areas in this type where trampling is intense but vegetative cover is desired, i.e., the mountain restaurant.

FORB COMMUNITY

Bluebell. This is restricted to moist, running water sites which are shaded. It is perhaps present as a result of logging activity since it is adjacent to a clear cut. Few other species are present. Development hazard is moderate because of the easy erodibility of the soil there.

Coneflower-Horse Mint-Cow Parsnip. In its pure form this is found at the fork of Red Canyon Creek where abundant subsurface water allows its growth. It is sometimes found under extremely moist aspen stands. These tall, approximately four foot, forbs are found with bluebell and Carex podocarpa, plus other water loving species. The presence of this type gives warning to soft, moist soil underneath so development hazard is moderate.

RUSH-SEDGE COMMUNITY

Rush-Sedge. This lakeshore type is limited to a narrow band at the most ten feet wide. It is dominated by several species each of rushes and sedges. Where found the lakeshore is gentle and rich in organic matter, clay, and silt, not rocky. It is important for its protection of the shore against wave action, shorebird foraging use, and receives some duck nesting use. Development hazard is moderate. Human use of this type should be directed to a particular site where an adequate beach might be maintained.

DISCUSSION

Vegetation of the Mt. Hebgen area will be altered and, in some cases, degraded by the proposed development. This will be most severe in areas where obliteration of vegetation will occur. However, construction activities may be planned and human use directed to lessen the negative impact. For example, construction vehicular activity should be avoided early in the summer or following heavy rains in any area where vegetation is to be retained. Vehicles on wet soil will quickly tear up the plants and begin slow-healing ruts. In this regard the forest understory and shallow soil areas are much more vulnerable and slower in recovery than other types. In fact, vehicles should be confined to clearings or forest areas that will be cleared. Also to be avoided are sagebrush-balsamroot communities which have very shallow, rocky soils and are sparsely vegetated.

Most areas of the site if disturbed during construction will respond well to seeding of Kentucky bluegrass (Poa pratensis) and other common grasses, such as timothy (Phleum pratense), (Watson et al 1970 and Wager 1971). Rhizomatous grasses such as Kentucky bluegrass are preferable to bunch grasses as they will provide more ground cover and better resist trampling. Mulching will accelerate revegetation.

Skier use of the natural vegetation types and cleared areas will have little impact on the vegetation if snow cover is present during use. However, snow bare sites will be quickly degraded by skiing (Bayfield 1970). Hiker use will occur directly on the vegetation and should be directed onto trails to concentrate trampling and lessen impact (Dale 1973 , Bayfield 1970, and Burden and Randerson 1972). The proposed restaurant site will receive heavy pedestrian use and trails are essential there. Trails should be built on elevation contours, should avoid seep or spring areas, and are more essential in forest than non-forest types. A trail system could be built on a nature trail basis to display the various ecosystems and plant species of the site.

Summer irrigation of slope areas with sewage effluent would increase productivity, total plant cover, and speed vegetation recovery from disturbance, but it would dramatically decrease vegetation diversity (Van Der Maarel 1970). Net impact would be slightly negative from the present state. If this action is undertaken the water should not be allowed to run over the surface which would increase erosion potential. Irrigation should cease when saturation of soil is evident. The hydrology report indicates that the soils have a great water-absorbing capacity which makes sprinkling irrigation feasible.

Snow making activities are most likely to negatively affect the vegetation by shortening the growing season which will offset any increase in water availability. This also pertains to snowdrift causing activities such as snow fencing. Plant cover diversity, and productivity will decline if snow pack is appreciably increased beyond natural levels (Weaver 1972 and Haglund 1972). However, a minimal amount of this may not be serious and may be necessary to cover bare areas on ski slopes.

Some shrub and shrub-grassland sites; for example, the sagebrush-snowberry type, may interfere with skiing because of their tall, dense shrub patches. Cutting of this shrubbery has been proposed. If necessary to do this for skiing the following precautions will help to mitigate impact; use rubber tired vehicles for the operation; combine cutting and seeding operations, if possible; and leave a buffer strip of shrubs between the mown area and forest for wildlife. The larger the buffer strip, the better for elk calving and blue grouse brood rearing purposes. The mowing would best be done in the fall with dry soil conditions and to allow seeds to break dormancy over winter. The "green manuring" effect of decaying roots and mulch, plus some increase in available moisture, should enhance revegetation to grasses (Daubenmire 1970). However, an alteration of community composition and a decline in diversity is unavoidable by this approach.

Forest types will be cleared to a small degree for ski runs and lifts. This will increase community diversity and the resultant communities, if natural revegetation is allowed, will be more diverse than the original forest. Even large clear cuts on the area have naturally revegetated in a few years. In the cleared forests seeding may not be necessary but preliminary mulching will accelerate revegetation to meadow species. Considerations which avoid ruts would lessen impact.

The production of small clearings may have a net positive effect by increasing blue grouse summering habitat and general small mammal habitat. Big game cover habitat would decrease, but summer forage would increase. However, present clearing plans would eliminate a goshawk nest site and open up a lodgepole pine-grouse whortleberry community to wind damage near proposed lifts M, N, and O. Perhpas these lifts could be moved northward to partially avoid these hazards.

As the final stage of sewage treatment for the Ski Yellowstone community sprinkler irrigation of tertiarily treated sewage on hay fields has been suggested. Two grass species, orchard grass (Dactylis glomerata) and smooth brome (Bromus inermis) are recommended. They both have high nitrate and water requirements and produce high quality hay. Legumes such as alfalfa (Medicago sativa) should be avoided because of nitrogen fixing bacteria and blue-green algae on their roots.

Two possible sites exist for this stage of sewage treatment. One, the Red Canyon Creek alluvial fan is presently dominated by cultivated grasslands which include smooth brome. On the other suggested site near the Duck Creek Wye the vegetation is presently big sagebrush-Idaho fescue but appears suited for orchard grass and smooth brome with irrigation and nitrate supply. Seeding rate for the grass mixture is recommended at: smooth brome 3.5 pounds/acre PLS (pure live seed) and orchard grass 2.0 pounds/acre PLS. Hay cropping of these stands is desirable. Tree farming of these lands appears less feasible.

Tree species which are native and feasible for decorative plantings include: Douglas fir, juniper, mountain maple (*Acer glabrum*), limber pine (*Pinus flexilis*), and perhaps others. These should maintain themselves with a minimum of maintenance.

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<u>TABLE 1</u>

Structural Type: Coniferous Forest

Floristic Type: Douglas fir - Snowberry (Pseudotsuga Menziesii - Symphoricarpos albus)

Height and appearance: Mature trees - seedlings of Douglas fir, low shrub layer (1'-3') of snowberry, buffaloberry and juniper, forbs and grasses and sedges.

Aspect: S,W,&E. Degree of slope: Variable, rarely level.
Altitude: 6805-8000'
Comments: Climax vegetation. Some charcoal present indicating a fire history.

Associated species: Arnica cordifolia, Achillea millefolium, Arctostaphylos uva-ursi, Antennaria rosea, Anemone multifida, Agoseris glauca, Arenaria congesta, Arabis sp. Arnica longifolia, Artemisia tridentata, Artemisia cana, Astragalus spp.
Balsamorhiza sagittata, Berberis repens, Bromus marginata,
Carex geyeri, Calamagrostis canadensis, Castilleja spp.
Clematis columbiana, Clematis hirsutissima,
Dodecatheon conjugens, Draba sp., Delphinium, Descurainia sp.,
Erigeron peregrinus, Festuca idahoensis, Fragaria virginiana, Erythronium grandiflorum, Erysimum asperum, Epilobium angustifolium, Eriophyllum lanatum, Eriogonum umbellatum,
Galium boreale, Geranium viscossissium, Geum triflorum,
Hieracium gracile, Hackelia floribunda, Hydrophyllum capitatum,
Juniperus communis, Lithophragma sp., Lapinus sericeus,
Lomatium dissectum, Lomatium cous, Linum perenne,
Melica spectabilis, Microsteris sp., Myosotis sylvatica,
Potentilla grocilis, Potentilla ovina, Phacelia hastata, Phlox hoodii,
Pinus albicaulis, Pinus contorta, Prunus virginiana, Poa pratensis,
Phleum pratense, Picea engelmonni, Pseudotsuga menziesii, Populus tremuloides,
Ribes sp., Rosa woodsii,
Senecio integerrimus, Symphoricarpos albus, Smilocine rocemoso,
Thalictrum venulosum, Taroxacum officinale, Thelypodium integrifolium,
Thlospi arvense, Trifolium sp., Tragopogon dubius,

Stipa columbiana, Danthonia sp.,
Delphinium occidentale, Valeriana occidentalis,
Viola adunca, Viola orbiculata

TABLE 2

Structural Type: Coniferous forest

Floristic type: Douglas fir - (Subalpine fir) - Snowberry
Pseudotsuga menziesii - (*Abies lasiocarpa*) - *Symphoricarpos albus*

Height and appearance: Mature trees of Douglas fir and occasionally subalpine fir. Seedlings of subalpine fir. Low shrub layer of snowberry and buffaloberry. Forbs, grasses, and sedges.

Aspect: E,N Degree of slope: Variable
Altitude:
Comments: Seral stage of vegetation will become subalpine fir - Grouse whortleberry without disturbance.

Associated species: *Aquilegia flavescens*, *Achillea millefolium*, *Arnica cordifolia*, *Agoseris glauca*, *Astragalus* spp., *Agropyron subsecundum*, *Abies lasiocarpa*, *Aster perelegona*, *Allium* sp., *Epilobium angustifolium*, *Carex geyeri*, *Berberis repens*, *Cypripedium montanum*, *Calamagrostis canadensis*, *Delphinium nuttalli*, *Castilleja* spp., *Cirisium* sp., *Hieracium gracile*, *Donthonia*, *Geranium viscossissium*, *Fragoria virginiana*, *Erythronium grandiflorum*, *Erigeron peregrinus*, *Senecio integerrimus*, *Clematis columbiana*, *yrola secunda*, *Pedicularis bracteosa*, *Linnea borealis*, *Poapratensis*, *Shepherdia canadensis*, *Juniperus communis*, *Ribes* sp., *Rubus parviflorus*, *Ronunculus* spp., *Smilacina racemosa*, *Thalictrum venulosum*, *Trifolium* sp., *Spiraea betulifolia*, *Vaccinium scopularum*, *Valeriana occidentale*, *Viola orbiculata*

TABLE 3

Structural Type: Coniferous Forest

Floristic Type: Douglas Fir - Whitebark Pine - Balsamroot (Pseudotsuga menziesii - Pinus albicaulis - Balsamorhiza sagittata)

Height and Appearance: Mature trees (scattered) - few seedlings of Douglas Fir and less common Whitebark pine. Scattered low shrubs. Forb patches of Balsamroot. Scattered grasses and forbs.

Aspect: S Degree of slope: Steep to very steep.
Altitude: 7800-8600'
Comments: ground cover sparse, soil thin, rock rubble often exposed. Dries up quickly.

Associated species: Agropyron spicatum, Antennaria rosea, Artemisia tridentata, Astragalus spp., Agoseris glauca, Arenaria congesta, Aster perelegona, Achillea millefolium, Viola nuttalli, Arnica lonchophylla, Balsamorhiza sagittata, Berberis repens, Bromus marginata, Besseya cinerea, Eriogonum umbellatum, Dicentra uniflora, Claytonia lanceolata, Fritillaria pudica, Erythronium grandiflorum, Carex geyeri, Dodecatheon conjugens, Draba, sp., Descurainia sp., Festuca idahoensis, Eriophyllum lanatum, Hackelia floribunda, Castilleja spp., Hydrophyllum capitatum, Linum perenne, Lactuca serriola, Lupinus sericeus, Juniperus communis, Lomatium cous, Delphinium nuttalli, Erigeron peregrinus, Hieracium gracile, Melica spectabilis, Microsteris sp., Phacelia hastata, Physalia sp., Penstemon fruoticosa, Taraxacum officinale, Symphoricarpos albus, Thelypodium integrifolium, Tragopogon dubius, Sedum stenopetalum, Senecio integerrimus, Stipa comato,

TABLE 4

Structural Type: Coniferous Forest

Floristic Type: Subalpine fir - Grouse Whortleberry (Abies lasiocarpa - Vaccinium scoparium)

Height and appearance: Mature trees about 60' tall to seedlings. Ground cover variously dense or sparse of scattered shrubs and forbs.

Aspect: N,E,W Degree of slope: Gentle to Steep
Altitude: 7000' - 8500'
Comments: Climax vegetation on much of area.

Associated Species: Abies lasiocarpa, Achillea millefolium, Antennaria rosea, Arnica cordifolia, Arnica latifolia, Aster engelmanni, Aquilegia flavescens, Berberis repens, Bromus anomalus, Corex geyeri, Castilleja sp., Epilobium angustifolium, Erigeron peregrinus, Corex Podocarpa, Juncus sp., Eriogonum umbellatum, Erythronium grandiflorum, Fragaria virginiana, Hieracium gracile, Lupinus sericeus, Pedicularis bracteosa, Poa pratensis, Poa sp., Pyrola secunda, Rubus parviflorus, Senecio sp., Spiraea betalifolia, Symphoricarpos albus, Thalictrum venulosum, Vaccinium membronaccum, Vaccinium scoparium, Viola orbiculatis, Shepherdia canadensis, Picea engelmanni, Pinus cartorta, Pseudotsuga menziesii,

TABLE 5

Structural Type: Coniferous Forest

Floristic Type: Subalpine fir - Whitebark Pine - Grouse Whortleberry (*Abies lasiocarpa* - *Pinus albicaulis* - *Vaccinium scoparium*)

Height and appearance: Clumps of mature trees usually less than 40' tall amidst other vegetation types. Subalpine fir is more abundant than whitebark pine. Sparse understory vegetation.

Aspect: N,E,W Degree of slope: Gentle to moderate
Altitude: 7800' - 8700'
Comments: Climax vegetation on the ridge tops. Makes a matrix with Idaho fescue grassland and the big sagebrush - Idaho fescue type.

Associated Species: *Achillea millefolium*, *Antennaria rosea*, *Arnica cordifolia*, *Arnica latifolia*, *Aster engelmanni*, *Agoceris glauca*, *Corex geyeri*, *Aquilegia flayescens*, *Astragalus* sp., *Galium boreale*, *Shepherdia conadensis*, *Erythronium granditlorum*, *Erigeron peregrinus*, *Fragaria virginiana*, *Hieracium gracile*, *Jancus* sp., *Lupinus* sp., *Poa* sp., *Pyrola secunda*, *Pedicularis bracteosa*, *Polygonum bistortoides*, *Senecio* sp., *Tholictrum venulosum*, *Rubus parviflorus*, *Sedum stenopetalum*, *Vaccinium scoparium*,

TABLE 6

Structural Type: Coniferous Forest

Floristic Type: Lodgepole Pine - Grouse Whortleberry (Pinus contorta - Vaccinium scoparium)

Height and Appearance: Dense stands of even - aged lodgepole pines. Mostly greater than 40' tall. Subalpine fir seedlings and saplings common. Sparse ground cover of few species.

Aspect: N,E,W Degree of slope: Gentle to Moderate
Altitude: 6800' - 8000'
Comments: Present because of past fires. Will be replaced by subalpine fir - grouse whortleberry in natural succession.

Associated Species: Abies lasiocarpa, Arnica latifolia, Arnica cordifolia, Achillea millefolium, Arctostaphylos uva - wsi, Astragalus spp., Aquilegia flavescens, Berberis repens, Carex geyeri, Calomagrostis canadensis, Castilleja miniata, Claytonia larceolata, Clematis columbiana, Epilobium angustifolium, Erigeron peregrinus, Eriogonum umbellatum, Eryphronium grondiflorum, Fragaria virginiana, Hieracium gracile, Picea engelmanni, Pinus contorta, Pedicularis bracteosa, Pyrola secunda, Poa pratensis, Rubus parviflorus, Shepherdia canadensis, Symphoricarpos albus, Spiraea betulifolia, Senecio sp., Thalictrum venulosum, Viola adunca, Viola orbiculatis,

TABLE 7

Structural Type: Coniferous Forest

Floristic Type: Engelmann Spruce - Grouse Whortleberry (*Picea engelmanni* - *Vaccinium scoparium*)

Height and Appearance: Mature trees often greater than 50' tall. Intense shading effect with sparse understory beneath forest canopy. Understory of scattered small forbs.

Aspect: N Degree of Slope: Moderate
Altitude: 6800' - 7800'
Comments: Subalpine fir often seen as saplings in this type. This type occurs in drainage pockets with much shade and cold air drainage effects. Very limited in distribution on site.

Associated species: *Arnica cordifolia*, *Abies lasiocarpa*, *Achillea millefolium*, *Aquilegia flavescens*, *Carex* sp., *Fragaria virginiana*, *Juncus* sp., Lichens, Mosses, *Pyrola secunda*, *Pedicularis bracteosa*, *Symphoricarpos albus*, *Smilacina racemosa*, *Thalictrum venulosum*, *Vaccinium* scoparium, Viola orbiculatus,

TABLE 8

Structural Type: Coniferous Forest

Floristic Type: Engelmann Spruce - Willow (Picea engelmanni - Salix spp.)

Height and Appearance: Mature - seedling Spruce trees, Shrub layer, grasses, forbs, and sedges.

Aspect: N,E,S,W Degree of Slope: Moderately Steep - nearly level.
Altitude: 6800' -
Comments: Restricted to stream bottoms and springs within the canyon or with narrow slopes adjoining for additional shading effect. Often found on slump areas.

Associated Species: Abies lasiocarpa, Astragalus sp., Anemone multifida, Arenaria congesta, Allium sp., Antennaria rosea, Bromus marginata, Berberis repens, Circium vulgare, Cirsium sp., Castilleja spp., Carex geyeri, Carex podocarpa, Carex spp., Juncus spp., Eriogonum umbellafum, Equisetum sp., Fragoria virginiana, Geranium richardsonii, Geranium viscossissium, Galium boreale, Juniperus communis, Hackelia floribunda, Erythronium grandiflorum, Heracleum lanatum, Festuca idahoensis, Lupinus sericeus, Potentilla fruticosa, Potentilla gracilis, Potentilla ovina, Pinus contorta, Populus tremuloides, Poa pratensis, Poa sp., Mimulus lewissia, Suxifraga arguta, Rosa woodsii, Shepherdia canadensis, Populus tremuloides, Mosses, Salix drummondiana, Salix farrae, Salix sp., Taraxacum officinale, Thalictrum venulosum, Trifolium hybridum, Valeriana occidentale, Viola adunca, Viola orbiculatus, Lichens, Liverworts

TABLE 9

Structural Type: Deciduous Forest

Floristic Type: Aspen

Height and Appearance: Mature aspen trees - saplings. Dense understory vegetation of shrubs, grasses, sedges, and forbs. Understory varied depending on aspect.

Aspect: W,S,E Degree of slope: level - moderate
Altitude: 6600-7200'
Comments:

Associated Species: Artemisia tridentata, Agropyron subsecundum, Agropyron spicatum, Arnica longifolia, Aster perelegona, Achillea millefolium, Antennaria rosea, Agoseris glauca, Anemone multifida, Arnica cordifolia, Arenaria congesta, Allium sp., Arabis sp., Arctostaphylos uva-ursi,
Berberis repens, Balsamorhiza sagittata, Carex geyeri, Corex sp., Castilleja spp., Danthonia sp., Cirsium vulgare, Clematis hirsutissima, Cirsium sp., Claytonia lanceolata, Fragaria virginiana, Fritillaria pudica, Erigeron peregrinus, Erysimum asperum, Erythronium grandiflorum, Epilobium angustifolium, Festuca idahoensis, Geum triflorum, Hackelia floribunda, Heracleum lanatum, Hieracium gracile, Hydrophyllum lonatum, Geranium richardsonii, Geranium viscossissium, Galium boreale, Lomatium cous, Lithophragma sp., Lactuca serriola, Koeleria cristata, Lupinus sericeus, Juniperus communis, Potentilla gracilis, Potentilla ovina, Rumex poucifolius, Trifolium hybridum, Poa pratensis, Phleum pratense, Stripa comata, Pseudotsuga menziesii, Pinus contorta, Picea engelmanni, Phleum alpinum, Calamagrostis canadensis, Rosa woodsii, Symphoricarpos albus, Thelypodium integrifolium, Senecio sp., Senecio integerrimus, Taraxacum officinale, Shepherdia canadensis, Valeriana occidentale, Perideridia gairdneri, Thalictrum venulosum, Viola adunco, Viola nuttalli, Thlaspi arvense, Mertensia ciliata, Microsteris gracile, Zygadenus venosus, Ranunculus sp., Thlaspi fendleri, Penstemon procerus, Potentilla fruticosa, Rudbeckia occidentalis, Monarda fistulosa

TABLE 10

Structural Type: Shrub Community

Floristic Type: Big Sagebrush - Snowberry (Artemisia tridentata - Symphoricarpos albus)

Height and Appearance: Clumps of shrubs up to four feet tall. Scattered Douglas fir, subalpine fir and whitebark pine trees. Ground coverlow with scattered grasses and forbs.

Aspect: SE   Degree of slope: Gentle to Steep.
Altitude: 8000'
Comments: May be a recently burned Douglas fir - snowberry stand. Charcoal and charred stumps are evident. Rockrubble on surface.

Associated Species: Artemisia tridentata, Achillea millefolium, Astragalus spp., Aster integrifolius, Bromus marginata, Agropyron subsecundum, Agropyron spicatum, Balsomorhiza sagittata, Corex podocarpa, Corex brevior, Corex geyeri, Corex sp., Dicentra uniflora, Eriogonum umbellatum, Descurainia spp., Penstemon proceius, Erysimum asperum, Lomatium dissectum, Erigeron speciosus, Lactuca serriola, Erythronium grandiflorum, Penstemon fruticosa, Phacelia hastata, Linum perenne, Lupinus sericeus, Smilacina racemosa, Delphinium occidentale, Delphinium nuttallianum, Hieracium gracile, Agoceris glauca, Senecio integrifolium, Symphoricarpos albus, Stipa comata, Taraxacum officinale, Thalictrum venulosum, Valeriana occidentale, Microsteris sp.

TABLE 11

Structural Type: Shrub Community

Floristic Type: Willow (Salix spp.)

Height and Appearance: Composed of dense shrubs in overstory, usually 10' - 15' tall. Clumping is evident except in a few areas where shrubbery is nearly continuous. Grasses, sedges, and forbs also present.

Aspect: N,E,S,W Degree of slope: Steep banks to level.
Altitude: 6550' - 7120'
Comments: Restricted to active stream channels and adjacent seeps. Aids in stream stabilization. Often three zones of vegetation: 1) water edge willows, 2) Rose, shrubby cinquefoil and big sagebrush zone, and 3) Big sagebrush and grasses on old banks distant from present stream.

Associated Species: Allium sp., Antennaria rosea, Astragalus spp., Anemone multifida, Artemisia cona, Artemisia tridentata, Saxifraga arguta, Bromus marginata, Bouteloua gracilis, Berberis repens, Delphinium nuttalli, Castilleja spp., Cirsium sp., Equisetum sp., Erigeron sp., Eriogonum umbellatum, Erysimum asperum, Festuca idahoensis, Fragaria virginiana, Galium boreale, Geronium richardsonii, Geronium viscussissium, Hackelia floribunda, Heracleum lanatum, Rudbeckia occidentalis, Linum perenne, Lupinus sericeus, Mertensia ciliata, Lycopodium spp., Juniperus communis, Poa pratensis, Phleum pratense, Potentille gracilis, Potentilla ovina, Potentilla fruticosa, Rosa woodsii, Oxytropis sp., Shepherdia canadensis, Smilacina racemosa, Stipa comata, Taraxacum officinale, Thalictrum venulosum, Trifolium longipes, Trifolium hybridum, Salix drummondiana, Salix farrae, Salix lutea, Valeriona occidentale, Viola adunca,

TABLE 12

Structural Type: Shrub - grassland

Floristic type: Big Sagebrush - Idaho fescue
Artemisia tridenta - *Festuca idahoensis*

Height and appearance: Shrub layer, Grasses, Forbs, and sedges

Aspect: W,S,E, Degree of slope: level - moderate
Altitude: 6600-8600'
Comments: Big sage and Idaho fescue fluctuate in dominance depending on site.

Associated species: *Achillea millefolium*, *Aster perelogona*, *Arabis* sp., *Anemone multifida*, *Antennaria rosea*, *Agoseris glauca*, *Arnica longifolia*, *Artemisia tridentata*, *Agropyron subsecundum*, *Agropyron spicatum*, *Agropyron spicatum*,
Besseya cinerea, *Bromus marginata*, *Berberis repens*, *Balsamorhiza sagittata*, *Clematis hirsutissima*, *Cirsium vulgare*, *Cirsium* sp., *Claytonia lanceolata*, *Carex brevior*, *Carex geyeri*, *Carex podocarpa*,
Dodecatheon conjugens, *Descurainia* sp., *Draba* sp., *Castilleja* sp., *Camponula rotundifolia*, *Danthonia* sp., *Draba* sp., *Dodecatheon conjugens*, *Eriogonum umbellatum*, *Eriophyllum lanatum*, *Geranium viscossissium*, *Frasera speciosa*, *Geum triflorum*, *Festuca idahoensis*, *Galium boreale*, *Hieracium gracile*, *Hackelia floribunda*, *Lupinus sericeus*, *Koeleria cristafa*, *Phlox hoodii*, *Poa pratensis*, *Phleum pratense*, *Phleum alpinum*, *Potentilla gracilis*, *Potentilla ovina*,
Rumex pacuifolius, *Trisetum spicatum*, *Trifolium longipes*, *Trifolium hybridum*, *Tragopogon dubius*, *Thlaspi fendleri*, *Thlaspi arvense*, *Taraxacum officinale*, *Thelypodium integrifolium*,
Senecio integerrimus, *Symphoricarpos albus*, *Stipa comate*, *Smilacina racemosa*, *Zygadenus venosus*, *Rumex paucifolius*, *Rosa woodsii*, *Thalictrum venulosum*,

TABLE 13

Structural Type: Shrub - Grassland

Floristic Type: Big Sagebrush - Hoary Sagebrush - Idaho fescue (Artemisia tridertata - Artemisia cana - Festuca idahoensis)

Height and Appearance: Shrubs, usually about three feet tall very common with abundant ground cover of grasses, sedges and forbs.

Aspect: S Degree of slope: Gentle
Altitude: 6550' - 6720'
Comments:

Associated Species: Artemisia tridentata, Potentilla fruticosa, Symphoricarpos albus, Rosa woodsii, Artemisia cana, Agropyron subsecundum, Agropyron repens, Hordeum sp., Donthonia sp., Stipa comata, Festuca idahoensis, Koeleria cristata, Corex spp., Poa pratensis, Phleum pratense, Rhleum alpinum, Bromus marginata, Corex podocarpa, Geranium viscossissium, Potentilla gracilis, Potentilla ovina, Tragopogon dubrius, Geum triflorum, Hackelia floribunda, Lupinus sericeus, Taraxaium officinale, Saxifraga rhombdoidea, Eriogonum umbellatum, Antennaria rosea, Clematis hirsutissima, Agoseris glauca, Rumex paucifolius, Trifolium hybridum, Trifolium longipes, Fragoria virginiana, Penstemon proceius, Delphinium nuttallianum, Erysimum aspeium, Achillea millefolium, Thelypodium integrifolium, Arenoria congesta, Phlox hoodii, Anemone multifida, Frasera speciosa, Senecio integerrimus, Galium boreale, Zygadenus venosus, Eriophyllum lonatum, Berberis repens, Cirsium vulgare, Smilacina racemosa, Microsteris sp., Viola adunca, Dodecatheon conjugens, Ranunculus sp., Claytonia lanceolata, Erythronium grondiflorum, Draba mermosa, Arabis sp., Thlaspi arvense, Camponula rotundifolia,

TABLE 14

Structural Type: Shrub - Grassland

Floristic Type: Big Sagebrush - Wheatgrass (*Artemisia tridentata* - *Agropyron spicatum*)

Height and Appearance: Sagebrush clumps with assorted grasses, forbs and sedges. Usually less than three feet tall.

Aspect: S Degree of slope: Moderate to Steep.
Altitude: 6600' - 8000'
Comments: Arid vegetation type, often with sparse plant cover and abundant rock rubble.

Associated Species: *Artemisia tridentata*, *Agropyron spicatum*, *Agropyron subsecundum*, *Antennaria rosea*, *Achillea millefolium*, *Berberis repens*, *Bromus marginata*, *Agoceris glauca*, *Balsamorhiza sagitatta*, *Clematis hirsutlissima*, *Castilleja* spp., *Aster* spp., *Eriogonum umbellatum*, *Eriophyllum lanatum*, *Erigeron speciosus*, *Geranium viscossissium*, *Carex geyeri*, *Carex filifolia*, *Campanula rotundifolia*, *Lactuca serriola*, *Linum perenne*, *Lupinus sericeus*, *Saxifraga rhombdoidea*, *Sedum stenopetalum*, *Selaginella* sp., *Potentilla gracilis*, *Tragopogon dubius*, *Stipa cemata*, *Taraxacum officinale*, *Senecio integerrimus*, *Valeriana occidentale*,

TABLE 15

Structural Type: Shrub - Grassland

Floristic Type: Big Sagebrush - Balsamroot (Artemisia tridentata - Balsamorhiza sagitatta)

Height and Appearance: Scattered shrubs and scattered forbs about three feet tall. Sparse ground cover with associated grasses and forbs.

Aspect: E,S,W Degree of slope: Moderate to very steep.
Altitude: 7600' - 8700'
Comments: Rock rubble abundant on soil surface. Very dry vegetation type. Revegetation capability low. Occurs on rock outcrops.

Associated Species: Astragalus sp., Artemisia tridentata, Antennaria rosea, Aster perelegona, Agoseris glauca, Agropyron spicatum, Agropyron subsecundum, Achillea millefolium, Berberis repens, Corex filifolia, Arenaria congesta, Balsamorhiza sagitatta, Delphinium nuttallianum, Dicentra uniflora, Clematis hirsutissima, Eriophyllum lanatum, Cirsium sp., Chrysothomnos nauseoris, Lupinus sericeus, Erigeron speciosus, Geum triflorum, Koeleria cristata, Castilleja spp., Bromus marginata, Lactuca serriola, Lomatium caus, Linum perenne, Penstemon proceius, Viola nuttalli, Phacelia hastata, Phacelia sericea, Tragopogon dubius, Symphoricarpos albus, Poa pratensis, Stipa cemata, Selaginella sp., Prunus virginiana, Juniperus communis, Hydrophyllum capitatum, Phlox hoodii, Pinus albicaulis, Pseudotsuga menziesi, Taraxacum officinale, Viola nuttalli, Thalictrum venulosum, Smilacina racemosa, Eriogonum umbellatum, Melica spectabilis, Corex sp., Microsteris sp., Arnica lonchophylla, Fritillaria pudica, Claytonia larceolato, Ranumulus spp., Dodecatheon conjugens, Draba sp.,

TABLE 16

Structural Type: Shrub - Grassland

Floristic Type: Snowberry - (Douglas fir) - Fireweed (*Symphoricarpos albus* - (*Pseudotsuga menziesii*) - (*Epilobium angustifolium*)

Height and Appearance: Scattered trees remain that escaped logging. Stumps and logging slash present. Shrubs and young trees common with grasses, sedges and forbs.

Aspect: E,W   Degree of slope: Gentle to steep.
Altitude: 6960' - 7600'
Comments: Clear cut areas that were logged within the past ten years. Douglas fir and other trees have established and are growing up.

Associated Species: *Artemisia tridentata*, *Antennaria rosea*, *Rubus parviflorus*, *Ribes* sp., *Epilobium angustifolium*, *Pseudotsuga menziesii*, *Picea engelmanni*, *Pinus contorta*, *Abies lasiocarpa*, *Symphoricarpos albus*, *Fragaria virginiana*, *Shepherdia conadensia*, *Mertensia ciliata*, *Taraxaium officinale*, *Poa pratensis*, *Poa* sp., *Bromus marginata*, *Festuca idahoensis*, *Aquilegia flavescens*, *Valeriana occidentale*, *Thalictrum venulosum*, *Geranium viscossissium*, *Phlox hoodii*, *Galium boreale*, *Koeheria cristata*, *Jenius* spp., *Carex* spp., *Carex geyeri*, *Carex podocarpa*, *Lupinus sericeus*, *Castilleja* spp., *Achillea millefolium*, *Microsteris* sp., *Viola orbiculatis*, *Viola adunca*, *Viola ruttalli*, *Astragalus* sp., *Rumex paucifolius*, *Descuroinia* sp., *Praba mermosa*, *Vaccinium scoparium*, *Lithophragma* sp., *Clematis hirsatissima*, *Hackelia floribunda*, *Pensfemon proceius*, *Penstemon* sp., *Berberis repens*, *Zygadenus venosus*, *Malva* sp., *Pedicularis bracteosa*, *Hydrophyllum capitatum*, *Potentilla gracilis*,

TABLE 17

Structural Type: Grassland

Floristic Type: Kentucky bluegrass - Timothy - Smooth brome

Height and Appearance: Grasses and forbs predominate with few species associated. About three feet tall.

Aspect: S Degree of slope: Gentle
Altitude: 6550' - 6700'
Comments: Grasses and alfalfa were seeded into most of these areas for hay production after the land was plowed.

Associated Species: Bromus inermis, Achillea millefolium, Arabis sp., Carex spp., Cirsium sp., Cirsium vulgare, Antennaria rosea, Artemisia cana, Clematis acuminata, Galium boreale, Erysimum asperium, Festuca idahoensis, Lupinus sericeus, Agropyron repens, Danthonia sp., Medicago sativa, Microsteris sp., Draba mermosa, Potentilla gracilis, Melica spectabilis, Poa pratensis, Phleum pratense, Penstemon procerus, Geranium viscossissium, Stipa cemata, Companula rotundifolia, Taraxacum officinale, Thlaspi arvense, Thelypodium integrifolium, Trifolium hybridum, Trifolium longipes, Ranunculus sp., Delphinium occidentale, Rumex pausifolius, Viola adunca, Eriophyllum lanatum,

TABLE 18

Structural Type: Grassland

Floristic Type: Idaho fescue

Height and Appearance: Vegetation usually two feet tall or less. Some taller forbs are occasional. Grasses are bunch type.

Aspect: N,E,S,W Degree of slope: Level to gentle.
Altitude: 6800' - 8720'
Comments: Occurs on deep soil sites.

Associated Species: Aster perelegona, Achillea millefolium, Agropyron subsecundum, Antennaria rosea, Antennaria pulcherrima, Agoceris glauca, Arenaria congesta, Aster integrifolius, Bromus marginata, Castilleja spp., Cerastium arvense, Claytonia lanceolata, Arnica lonchophylla, Carex brevior, Carex spp., Danthonia sp., Delphinium occidentale, Delphinium nuttallianum, Epilobium angustifolium, Eriogonum umbellatum, Festuca idahoensis, Erigeron speciosus, Erythronium grandiflorum, Frasera speciosa, Galium boreale, Hieracium gracile, Balsamorhiza sagittata, Astragalus spp., Geranium viscossissium, Geum triflorum, Clematis hirsutissima, Hackelia floribunda, Oxytropis sp., Poa pratensis, Poa sp., Fritillaria pudica, Lupinus sericens, Koeleria cristata, Linum perenne, Lomatium cous, Lomatium dissectum, Perideridia gairdneri, Melica spectabilis, Microsteris sp., Thelypodium integrifolium, Phleum pratense, Phleum alpinum, Potentilla ovina, Potentilla gracilis, Ramex paucifolius, Ranunculus spp., Tragopogon dubius, Stipa cemata, Taraxacum officinale, Viola nuttalli, Campanula rotundifolia, Myosotis sylvatica, Lithophragma sp., Agastache articifolia, Valeriana occidentale, Draba mermosa, Thlaspi arvense, Arabis sp., Equisetum sp., Fragaria virginiana, Silene sp., Penstemon fruticosa, Dodecatheon conjugens, Descurainia sp., Senecio integrifolium, Saxifraga rhombdoidea,

TABLE 19

Structural Type: Forb Community

Floristic Type: Bluebell - (Mentensia ciliata)

Height and Appearance: Dense growth of forbs about three to four feet tall. Very few other species of grasses, sedges, and rushes.

Aspect: NE Degree of slope: Gentle

Altitude: 7280'

Comments: Found in one location adjacent to clear cut. Running water through community.

Associated Species: Carex podocarpa, Carex spp., Juncus spp., Bromus marginata, Equisetum sp., Mertensia ciliata, Mosses, Lichens, Liverworts, Saxifraga arguta,

TABLE 20

Structural Type: Forb Community

Floristic Type: Coneflower - Horse Mint - CowParsnip - (Rudbeckia occidentalis - Agastache urticifolia, Heracleum lanatum)

Height and Appearance: Dense growth of forbs often up to four feet tall. No trees or shrubs, but some grasses and sedges.

Aspect: N,E,S,W Degree of slope: Gentle
Altitude: 6800'
Comments: Found in one site at fork in Red Canyon Creek. Very moist soil, perhaps a seep.

Associated Species: Bromus marginata, Carex podocarpa, Descurainia sp., Carex sp., Juncus spp., Agastache urticifolia, Phleum alpinum, Phleum pratense, Poa pratensis, Heracleum lanatum, Mertensia ciliata, Stipa comata, Taxaxacum officinale,

TABLE 21

Structural Type: Rush - Sedge

Floristic Type: Rush - Sedge (*Juncus* spp. - *Carex* spp.)

Height and Appearance: Dense vegetation of grass-like plants, often found in clumps. Usually about 1'-2' tall. Wave washed and constantly wet soil.

Aspect: N,E,S,W Degree of slope: Nearly level
Altitude: 6550'
Comments: Dominated by several species each of *Juncus* and *Carex*. Very few other species except in dry microenvironments.

Associated Species: *Carex* spp., *Poa pratensis*, *Juncus* spp., *Rumex paucifolius*, *Bromus inermis*, *Phleum pratense*

WILDLIFE ECOLOGY

Brent M. Haglund

INTRODUCTION

Wildlife studies were conducted in the Mt. Hebgen area of the Gallatin National Forest and adjacent private lands during spring and summer, 1973. The wildlife research was part of a comprehensive planning and environmental impact study for a proposed ski resort-land development in the area, Ski Yellowstone, Inc. Investigations emphasized the game and fur-bearing animals of the site, notably the large ungulates; their winter range; migration routes; rare and endangered species, and a general review of animal components in the local ecosystems; and other potentially invaluable habitats.

The Mt. Hebgen area is located in the Hebgen Ranger District, Gallatin National Forest, Montana. Studies of big game were concentrated in the following areas: T. 11 S, R. 4 E.; T. 11 S., R 5 E.; northern part of T. 12 S., R. 4 E.; and the northern part of T. 12 S., R. 5 E. Basically this is from the northeast shore of Hebgen Lake, including the Grayling Arm, northward to the Cabin Creek and Tepee Creek basins. This includes most of the northern portion of the secondary study area. Small game and non-game species research emphasized the more limited primary area eastward, about one mile, and westward, about three miles, of Red Canyon Creek.

White man's use of the area's animals has been primarily through hunting, recreational viewing and trapping. In these respects the Hebgen area is most noted for its waterfowl hunting; elk and moose hunting; and waterfowl, big game, and raptor watching. Attitudes towards wildlife have ranged from dislike and hatred (e.g., Uinta ground squirrel and coyote) to tolerance to acceptance and to appreciation to vehement protectionism (e.g., local elk herds). (Harold Picton, 1972, personal communication) Numbers of wildlife present have constantly fluctuated in response to habitat changes, weather, variation in hunter harvest, and also recently in response to white man's building and recreational activities, e.g., highways, houses, and motor boats. The wildlife in its diversity has survived to the present because of largely intact habitat.

BASIC ASSUMPTIONS

The following eight assumptions are the basis for judging the effects of Ski Yellowstone development activities on the terrestrial plants and animals of the Mount Hebgen area. They are merely value judgments of ecological principles. Many are accepted for wildlife management purposes. A high value is placed on diversity. Diversity in the ecosystems provides stability and assures that the ecosystem can respond to environmental changes (Odum 1969 and Westhott 1970).

1. Organism "Worth". A rare organism at a site is "worth" more than a common organism. Therefore an impact that would remove five rare organisms is judged more severe than one that would remove five common organisms. Game animals, birds of prey, and fur-bearers are usually rarer because of greater food or territorial requirements than smaller animals such as mice. However, at the site some very small animals may also be rare.

2. Diversity of Species. A negative value is assigned to those impacts which would decrease the number of species, below natural levels, in a community.

3. Productivity. An increase in biological productivity within a particular community at the site is judged of positive value, e.g., more grass grown per acre in a summer in a bunchgrass community. Conversely a decline in productivity is judged of negative value. As an example, vehicle activity in a grassland would decrease productivity by trampling plants.

4. Species' Limiting Factors. If a limiting factor, such as available winter range, becomes more available to an organism that is accorded positive value. If it becomes less available and limits an organism even more it is negative.

5. Community Alterations. If a common community becomes more common it will receive a slight negative rating. If an uncommon community or habitat becomes more common that will receive a positive rating.

6. Edge Effect or Interspersion of Types. Increase in edge area between two communities is generally judged of positive value. That is because of a likely increase in plant diversity, plus animal numbers and species. However, community alterations which might increase edge between communities may have a negative aspect if the particular community to be altered is escape cover or nesting habitat which is especially valuable.

7. Community Obliteration. In the assessment of an activity such as parking lot paving the following values are used: obliteration of 0-25% of a community in an area, low impact; obliteration of 25-50%, moderate impact; and obliteration of greater than 50%, severe impact. Obliteration of rare or unique communities will be more strongly judged.

8. Erosion. Activities which would increase the rate of soil erosion, usually by decreasing plant cover, are negative impacts.

These assumptions are necessarily subjective but logically explain the rating system adopted by the author for analysis of the proposed Ski Yellowstone development.

METHODS

Direct observation was the primary method of wildlife investigation. Two flights, on May 31 and July 2, 1973, to observe big game and waterfowl were made specifically for this study. The pilot was Jim Stradley of Gallatin Flying Service. The records of recent Montana Fish and Game Department observations (Phillip Schladweiler and John Cada, 1973, personal communication) were made available and are included in this report. Aerial census of animals varies in effectiveness and is dependent upon the satisfactory interplay of many factors. Since many animals were not visible due to their location in heavy timber, the counts are merely minimal estimates of numbers. Many observations were also made on the ground, especially for the smaller species.

Fecal pellet groups of moose, elk, deer, bear and grouse were sampled by a transect method in the different environments of the primary study area. A foot transect was made through an area and all dropping groups were noted within two yards of the line. Length of transect line was measured and from these measurements the area sampled was determined. Analysis of pellet group counts produces an index to animal use of different habitats. This technique is useful to determine degree of use on winter range.

Tracks were noted while walking the transects and at other times. They are a subjective measure of animal use because of their ephemeral nature but were used to help determine location of migration routes. Some small mammal species are known to be present on the site because of the observation of tracks and droppings.

Conversation with area residents and the records of the Gallatin Flying Service (Jim Stradley, 1973, personal communication) also provided information on big game distribution.

On June 20, 1973 the Mt. Hebgen ridge and open slopes were searched for blue grouse. At this time a bird dog was used to point the birds. John Cada of the Montana Fish and Game assisted. The method entailed hiking through the area and flushing and counting grouse pointed by the dog. Characteristics of the sites where birds were found were analyzed.

The animal species present are representatives of the plant communities of the area which include, primarily; sagebrush-grassland, aspen stands, and coniferous forest types. Tables 1, 2 and 3 list the species found on the site by the researcher in 1973. More intensive watching will certainly expand the lists of land birds, bats and owls. A few species in Tables 1 and 3 were not seen on the site but are to be expected. They are noted. The following two amphibians and one reptile species were observed onthe site: northern toad (Bufo boreas), leopard frog (Rana pipiens), and wandering garter snake (Thamnopsis elegans).

Animal species nomenclature follows two sources: Peterson (1969) for birds and Wright (1972) for mammals.

RESULTS

One of the most desired wildlife species in the Mt. Hebgen area are elk. They were observed on many portions of the primary and secondary study areas. Largest numbers of elk occur on the primary study site during the winter as they utilize the area's south-facing slopes. The primary area receives only limited elk summer use.

On the flight of May 31, elk were observed. Most were seen in the Grayling Creek delta (two cows with calves) and in the Little Tepee Creek trail area just to the north. Others were seen just east of the mouth of Red Canyon Creek. The use of willows as an elk calving area is unusual since it is most often done in areas of interspersed sagebrush and timber (Johnson 1950). Most of the elk observed were migrating to summer ranges or were still on winter ranges. At that time summer ranges were still snow covered.

During June, elk were seen near the top of Mt. Hebgen and along the northward trending Mt. Hebgen ridge to Kirkwood Ridge. Two cow elk with newly born calves were located in NW 1/4, Sec. 2 and NE 1/4, Sec. 3 of T. 12 S., R. 4 E. This is typical elk calving habitat, that is Douglas fir timber stands interspersed with sagebrush grassland. The meadows on the ridge top seemed to be a migration path to the Cabin Creek basin summering area. Even the Red Canyon Creek road was traveled by cow and calf elk.

By late June and early July, elk were seen in large numbers in Cabin Creek and Tepee Creek basins (see appendix). Most of these elk are from wintering areas other than Red Canyon Creek. At this time elk were largely absent from lower portions of Red Canyon Creek. Based on these and other observations there appear to be three major elk migration routes to summer range (see Wildlife map, secondary study area). One in the Little Tepee Creek trail area, another in Mt. Hebgen Ridge, and a third in the vicinity of Kirkwood Trail and Creek. Migration to winter range is probably less concentrated although I have no specific information on that point.

Winter forage availability is the limiting factor to the Mt. Hebgen area elk. The most heavily used community at that time, based on fecal pellet counts, is big sagebrush-wheatgrass. This occurs predominantly in Sec. 1, 3, and 4, T. 12 S., R. 4 E., and Secs. 6, 7, and 12, T. 12 S., R. 5 E. In these areas the Douglas fir-snowberry stands supply cover and some forage. The aspen stands at lower elevations were also heavily used in the winter. Besides the grasses eaten under the trees many aspen are scarred by elk feeding on the food rich phloem layer under the bark.

The minimum number of elk wintering in the primary area is twenty. This is the number seen on Fish and Game Department flights (Phillip Schladweiler , 1973, personal communication) and by other persons (Jim Stradley, 1973, personal communication). This herd has been known to cross Red Canyon Creek frequently during the winter. Scattered elk winter to the east and west of

Red Canyon Creek, also. A large herd frequents the area of the Duck Creek Wye, but they apparently summer in Yellowstone Park.

Mitigation of the loss of elk on the primary area may be possible within the secondary area if cattle-elk forage competition is occurring. Cattle numbers could be adjusted downward to enhance elk numbers. However, if cattle and elk merely use the same area but competition is not taking place then removal of cattle would have no positive effect for elk. (Stevens 1966).

Moose are a major component of the Hebgen area wildlife. The major use area for these large deer is the Grayling Creek delta with its dense willow stand. Ten moose were observed there on the May 31 flight. A winter high population in the willow delta is perhaps 25-35 moose. No moose were observed there on the July 2 flight indicating their presence instead on summer range. The willows support moose from a large area, including perhaps the entire Grayling Creek watershed. Browse quality is high in the delta, and the Montana Fish and Game Department (John Cada, 1973, personal communication) is planning to increase the moose herd closer to carrying capacity by decreasing the number of moose hunting permits in the area.

Moose were observed in other communities during the study. Most frequently they were seen in sagebrush-grasslands and clear-cuts because of their high visibility there. However, they and their droppings were recorded in aspen, subalpine fir, lodgepole pine, and Douglas fir communities. Dropping counts were highest in Douglas fir and aspen stands. The willow stand was not sampled for this. Summer range is mostly in subalpine fir forests and their associated meadow. The appendix records locations of moose observed on the flights.

Migration routes of moose are most usually the drainage ways. Moose, however, are very mobile, and routes vary tremendously. Grayling Creek, Little Tepee Creek, and Red Canyon Creek were all used as paths to and from summer range (see secondary study area Wildlife map). Occasionally, moose seemed to move to summer range along ridges and through forests. Calving habits of moose are not well understood, but forest and shrub communities are most likely used as calving grounds. Certainly moose calves are born in the Grayling delta.

Aside from the willow delta the moose, on a less concentrated basis, use the low-lying Douglas fir and aspen forests for winter range (Stevens 1970.). Moose feeding craters and browsed aspen and willow were seen in Red Canyon Creek one mile north of Highway 191 on April 8, 1973. Several moose are reliant upon the Red Canyon Creek as a wintering area. Pellet counts indicate use of other drainage ways and low-lying slopes during the winter. Two successively larger pairs of antlers foundin NW 1/4, S. 2 T. 12S, R. 4E. indicates a bull moose has used a limited area for the past two winters.

Mule deer were found at very low densities near Mt. Hebgen. One was observed on the July 2 flight in a low-lying aspen stand. Other single mule deer were noted during the spring and summer grazing on forbs in fescue grasslands and clear cut areas. A surplus of summer forage for mule deer cannot overcome the handicap of virtually nonexistent winter range. Deer fecal pellets were noted only in the fescue grasslands and aspen stands.

Based on tracks, droppings and sightings some black bear were known to summer in the Red Canyon Creek area. Black bear foraging was especially noted around ant rich stumps and logs. On the July 2 flight two bears, one cinnamon phase and the other black phase, were very close to a group of cow elk in Tepee basin and may have been hunting elk calves. Habitat preference could not be determined on the basis of these observations for black bear.

A grizzly bear was also observed on the July 2 flight in the Tepee basin. It too, was quite close to a group of cow elk and may have been calf hunting. A grizzly was seen by the author in Cabin Creek basin on June 29. Perhaps these were observations of the same animal. Numerous grizzly tracks were seen on the May 31 flight in Cabin Creek, Tepee Creek and Grayling Creek drainages. Again, just a few animals may have made these tracks. Grizzly bear home range size is large and it is likely they occur occasionally south of Kirkwood Ridge.

Coyotes were noted during the study most frequently in grassland and sagebrush areas. The generally greater small mammal populations there in contrast to forest certainly attracted them. Howls could be heard nearly every night in the Red Canyon area.

Because of their generally small size and secretive behavior most other mammals native to the area were seen only rarely, if at all. As mentioned previously many were noted only by tracks and droppings. Exceptions, of course, are the non-secretive types, such as the squirrels. Table 1 associates these species with their most frequented habitat.

Especially abundant populations are the Uinta ground squirrels, montane voles in peak years of their cycles, western jumping mice, and deer mice. Because of their higher position on the food pyramid small carnivores are much less abundant. The marten, badger, and bobcat are rare in the area.

Two species of grouse frequent the Hebgen Area. They are: blue grouse, primarily in the open conifer forests, grasslands, and shrub communities of the ridge tops and slopes, and ruffed grouse in aspen stands and stream bottom forests. The blue grouse, larger of the two, is the more common as its favored habitat is so much more abundant. (Mussehl 1960). Many sightings were made of these grouse. Blue grouse females with broods were generally seen along the forest edge and into some shrub communities. Males seemed to be in small groups in scattered subalpine fir stands after the breeding season. Prior to breeding single grouse and small coveys were seen in many forest types and openings. Blue grouse droppings were most abundant in sagebrush-grasslands and ridge line timber stands.

During June male ruffed grouse were heard drumming from logs in stream bottoms and aspen stands, and Engelmann Spruce. No ruffed grouse were seen outside those forest types.

Canada geese are quite common around Hebgen Lake. Nesting and feeding habitats are available and used. Most nesting appears to take place in the willow communities adjacent to the lake (Childress 1972). Geese were observed during both observation flights and nest sites were noted. However, counts were extremely low because of the early hour of the flights. Besides use of the willow, nearby grasslands were intensively used as feeding areas for their supply of grass shoots sought out by the geese. Over sixty Canada geese were seen feeding on one grassland adjacent to the lake on the May 31 flight.

Sandhill cranes utilize nearly the same habitat as Canada geese and are frequently seen near Hebgen Lake. They and their young were observed in the Grayling Creek delta, on nearby grasslands, and even a mile north of Highway 287 in a sagebrush-fescue stand along Red Canyon Creek. In other nearby localities the author has observed them in aspen stands. Much of their diet is animal matter which separates them from vegetarian Canada geese.

Several species of waterfowl, mallards, gadwalls, and widgeon, were discovered on nests in the grassland and rush-sedge communities adjacent to Hebgen Lake. Most waterfowl use of the proposed development site is restriced to this lakeshore area. As expected, though, waterfowl use of the Grayling Creek delta was great. It supplies nest sites, food, and loafing areas for many waterfowl, plus a great variety of shorebirds. Resident birds are dwarfed in number and variety by the migrating flocks using the lakeshore and willow areas.

Hebgen Lake is used by a number of birds which utilize the fish of the lake as food source. Bald eagles, an endangered species, are sometimes seen over the lake. The author noted 18 bald eagles on Grayling Arm just before breakup in 1972. They seemed to be feeding on dead fish and other carrion. Ospreys fish more actively than bald eagles and are present around the lake. White pelicans are common on the lake.

Trumpeter swans, an endangered species, are residents on the lake, especially in Madison Arm. Nearby Red Rock Lakes Refuge and Yellowstone Park were refuges for these birds during their population low of the 1930's. Habitat maintenance and harvest restriction have allowed their numbers to expand since then.

Study of the birds associated with the lake was largely precluded by the geographic dimensions of this study. Yet the following species were observed on the lakeshore of the Red Canyon Creek alluvial fan: Killdeer (*Charadrius vociferus*), Great blue heron (*Ardea herodias*), solitary sandpiper (*Tringa solitaria*), American avocet (*Recurvirostra americana*), long-billed curlew (*Numenius americanus*), spotted sandpiper (*Actitis macularia*), willet (*Catoptrophorus semipalmatus*), long-billed dowitcher (*Limnodromus scolopaceus*), common snipe (*Capella gallinago*), and western sandpiper (*Ereunotes mauri*).

Several species of raptors (birds of prey) inhabited the Mt. Hebgen area and they are listed in Table 3. The golden eagle was seen occasionally, especially near Kirkwood Ridge. Three open country hawks, red-tailed hawks, Swainson's hawk, and marsh hawk, were commonly seen. As these three species migrate south for the winter they are replaced by rough-legged hawks which arrive from the north. Densities of these raptors are primarily dependent on density of their prey and as the prey is less common so are they. Two hawks are usually restricted to the forest, the goshawk and sharp-shinned hawk. The former is much larger and relatively rare. One goshawk nest was found on the proposed development site and was used successfully in 1973. Great horned owls were seen several times during the study, primarily in the aspen stands.

Table 2 lists the small terrestrial birds by species and by usual place of occurrence. Specific habitat requirements for most of these species are not well understood, but many are edge species and dependent on the jutaposition of plant communities. Numbers present reflect habitat availability, food abundance and territory size. Woodpeckers, especially Lewis' woodpecker, and warblers are known to respond dramatically to increased insect supplies such as follow forest fires (Skaar 1970).

DISCUSSION

Wildlife of the Mt. Hebgen area will be impacted by the proposed Ski Yellowstone ski area development and offshoot developments that are certain to follow. The following conclusions about degree of impact are based on a comparison of the present wildlife situation (above) and the proposed development plans with a peak use figure of 5000 persons per day in the winter and 3/4th that number in the summer. The IIIc development map of Beardsley, Davis Associates, Inc. was superimposed on a map of wildlife use areas and impacts were noted. Also, development of certain other private lands, not under ski area ownership, is considered. Degree of change in wildlife populations under the stress of recreational development is difficult to perceive exactly even in intensely studied areas. (Schnoogas & Franklin 1972). But the generally negative relationship especially for large animals has been recognized (Anon. 1971).

Elk will be negatively affected in several ways by the proposed development. The main development site, while not physically intruding upon much elk winter range will stop elk movement across the canyon mouth and prevent elk from using formerly available aspen stands. The restriction of the approximately twenty elk may cause a degradation of the range quality due to increased grazing pressure on the remaining range. Degree of degradation of forage and ultimately a decline in herd size is not entirely predictable but is dependent upon behavioral plasticity in the elk and the ability of the winter range, primarily big sagebrush-wheatgrass to be grazed.

Concentration of the village site will help to lessen the impact. Ski lifts C and E because of their proximity to the south facing slopes will accentuate the disturbance to wintering elk.

Elk bear calves on the site. Lifts A and D are at present planned to be built in the known calving area. It is possible that delaying of lift construction and summer lift use past June 15 may allow elk to continue to use the site. But this becomes a moot point if elk are displaced to the west of Mt. Hebgen for much of the winter and no longer use the Mt. Hebgen ridge for migration.

Skiers who might use the south facing area pose a potential disturbance to elk especially if ski runs are built in that area. The distrubance of the village and lifts will be most severe westward of the Red Canyon Creek mouth. Yet the village will disturb, to a limited degree, elk wintering east of the canyon. Disturbance will become much greater if other private lands such as those north of the Narrows camp are developed. Lifts planned for the Mt. Hebgen ridge will disturb elk migrating there. This general pattern of disturbance and movement of elk away from those areas is very similar to that taking place presently at the Big Sky development. There elk are moving out of traditional areas onto bighorn sheep range (Harold Picton, 1973, personal communication).

Summertime use of the area will not affect elk directly since very little elk summering takes place on the primary area. Elk, other than those at the immediate site, may be affected by offshoot development. Examples are the elk wintering near the Duck Creek Wye and Grayling Creek.

The village site and most of the proposed lifts and runs will impinge directly upon the moose wintering near the bottom of Red Canyon Creek. To an even greater degree than with the elk, moose winter range on the site is limited. Thus development and use will probably quickly reduce or eliminate the several primary area wintering moose. The possibility for mitigation of this impact seems low. But much more severe to moose would be development near or on the Grayling Creek delta. Since a good deal is in private ownership the likelihood for obliteration of some of some of the willow stand exists. The Grayling Creek willow delta in undoubtedly the most valuable single wildlife habitat within a large area.

A low level of disturbance may be expected for other big game species. The black bears may desert the primary area because of summertime activities. Mule deer may suffer mostly through increased winter food competition with the elk. Increased backpacker use of the Cabin Creek and Tepee Creek areas from Ski Yellowstone may hamper grizzly bear activities.

The small mammals will respond more directly to development than will large mammals. Smaller home ranges and shorter life spans are reasons for this. The Uinta ground squirrels and associated species living in the suggested village area will collapse in numbers as their sagebrush-grassland habitat is obliterated. This small mammal community includes montane voles, deer mice, and weasels. Small mammal numbers are likely to increase where trail and lift clearing creates additional edge from new openings in the forest. Perhaps the more rare or secretive species such as marten, bobcat, and coyote will move from the primary area under human use pressure.

The two grouse species may be affected but perhaps not measurably. Increased edge and greater interspersion of types may make available formerly unused area for the grouse. This may compensate for minor habitat losses due to construction.

Waterfowl and other lake associated species will be severely affected principally if the nearby Grayling Creek delta is disturbed. In the case of Canada geese and sandhill cranes some fields used as feeding grounds within the secondary area may disappear. Marina construction and housing will take away a limited amount of duck nesting ground on the Red Canyon alluvial fan. Agricultural use of a large part of the Red Canyon alluvial fan, as planned, will be consistent with waterfowl maintenance.

Open country raptors may move with decreased food availability on the village site. A goshawk, forest raptor, nest is located in the vicinity of proposed lifts M, N and O. Lift construction would force out the pair since they are known to require deep, secluded forests for nest sites (Bent 1938). On the other hand, forest raptors may be favored by an increased food supply in forests manipulated for ski runs.

As in the case of small mammals, small bird populations will be altered functionally with their habitat. Many species may increase, especially near the cleared ski runs. Those such as the Brewer's sparrow (sagebrush-grassland occurrence which are restricted in habitat preference will decline most markedly.

SUMMARY

Mitigation procedures to lessen the development's impacts on large mammals rests principally with habitat enhancement for elk off the primary site but within the secondary study area, and avoidance of construction in certain areas for elk and other species. Lessening the negative impact on moose may be impossible because their forage habitats do not usually overlap with cattle (McMillan 1953). It is not likely that winter foraging sites can be made more productive or available to moose after their exclusion from Red Canyon Creek following development. Black bears, mule deer, and grizzly bears because of their present low density populations may not respond measurably to the development but some minor negative impact will be felt by them.

The large birds frequenting Hebgen Lake will be affected in the same manner as elk. That is essential habitats will not in themselves be removed, but disturbance will prevent them from using previously used areas and restrict their movement. Examples of species perhaps to be affected this way are: sandhill cranes, Canada geese, trumpeter swans, ospreys, bald eagle, and white pelicans. Mitigation procedures are not likely to increase the availability of their limiting factors with the possible exception of Canada geese which might respond favorably to an increase in artificial nest sites if lack of them is restricting the population.

Smaller animal species offer greater possibilities for on site mitigation techniques. Where plant communities are obliterated the small animals will vanish but in other, less dramatically affected areas, such as the ski runs small animal numbers may actually increase despite a likely shift in species composition. Except for the more secretive species such as bobcat, marten, and some raptors this is likely to be the case.

Thus, the proposed Ski Yellowstone development will most likely cause decline or movements away from the area in large animals, may increase small animal numbers by manipulation of the vegetation, but will leave the basic ecological processes functioning except where obliteration of the vegetation occurs.

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APPENDIX

Flight Records, Big Game Observations
May 31, 1973

Species	Location	Habitat Type	Age A	Age Y	Age C	Sex M	Sex F	Number
Moose	S.28,T.11S.,	Boggy, adj.	X			X		1
"	R.5E.	spruce	X				X	1
Moose	Tepee Ck.	Boggy	X			X		1
Moose	S.10,T.12S.,	Aspen	X			X		1
"	R.5E.	"	X				X	1
"		"	X					1
Moose	S.17,T12S., R.5E.	Willows		X				1
Moose	S.35,T.11S., R.4E.	Clearcut	X				X	1
Moose	S.17,T.12S.,	Grassland	X			X		1
"	R.5E.	"	X			X		1
Moose	S.18,T.12S.,	Willows	X			X		1
"	R.5E.	"	X			X		1
Moose	Grayling	Willows	X			X		1
"	Delta	"		X				1
"	"	"	X				X	1
"	"	"	X				X	1
Elk	S.33,T.11S., R.5E.	Opening	X			X		1
Elk	S.19,T.11S.,	Opening in	X				X	6
"	R.5E.	Aspens						
"	"	"						
"	"	"						
"	"	"						
"	"	"						
"	"	"						
Elk	East of	Sagebrush	X				X	1
"	Red Canyon				X			1
Elk	S.6,T.12S., R.5E.	Sagebrush	X					1
Elk	East of Hwy. 191	Aspen	X			X		2
Elk	S.8.T.12S.,	Willows	X				X	1
"	R.5E.	"			X			1
Elk	S.18,T.12S.,	Willows	X				X	1
"	R.5E.	"			X			1
Elk	S.17,T.11S., R.4E.	Douglas Fir	X					2
Coyote	S.25,T.11S., R.4E.	Sagebrush	X					2

Flight Records, Big Game Observations
July 2, 1973

Species	Location	Habitat	Age A	Age Y	Age C	Sex M	Sex F	Number
Moose	Divide Lake	Willows	X				X	1
"	"	"	X				X	1
Moose	Grayling Ck.	Willows	X			X		1
Moose	S. 9,T.11S., R.4E.	Grassland	X				X	1
Moose	S. 8,T.11S., R.4E.	Grassland	X				X	1
Moose	S.23,T.11S., R.4E.	Sagebrush	X				X	1
Moose	S.13,T.11S.,	Grassland	X				X	1
"	R.4E.	"		X				1
Elk	S.8,T.11S., R.5E.	Grassland	X			X		2
Elk	S.17,T.11S., R.5.	Grassland	X				X	10
Elk	S.17,T.11S., R.5E.	Grassland	X			X		2
Elk	S.6,T.11S., R.5E.	Grassland	X				X	10
Elk	S. 6,T.11S., R.5E.	Grassland			X			2
Elk	S. 6,T.11S., R.5E.	Grassland	X			X		2
Elk	S.18,T.11S., R.5E.	Grassland	X				X	6
Elk	S. 7,T.11S., R.5E.	Grassland	X			X		4
Elk	S.11,T.11S., R.5E.	Grassland	X			X		4
Elk	Gully Ck.	Sagebrush	X			X		3
Elk	S.10,T.11S., R.4E.	Grassland	X			X		2
Elk	S. 5,T.11S., R.4E.	Grassland	X				X	20
Elk	S. 5,T.11S., R.4E.	Grassland			X			7
Elk	S. 6,T.11S., R.4E.	Grassland	X				X	2
Grizzly Bear	S. 1,T.11S., R.4E.	Grassland	X					1
Black Bear	S. 8,T.11S., R.5E.	Subalpine Fir	X					2
Mule Deer	S. 2,T.12S., R.4E.	Aspen	X				X	1
Mule Deer	S.18,T.11S., R.4E.	Grassland	X				X	2

TABLE 1
Hebgen Area Species List
Mammals

Common name	Specific name	Occurrence
Badger	Taxidea taxus	Non-Forest
Black bear G	Ursus americanus	Various
Bobcat *	Lynx rufus	Various
Coyote	Canis latrans	Various
Deer mouse	Peromyscus maniculatus	Various
Elk G	Cervus canadensis	Various
Grizzly bear G * †	Ursus arctos	Various
Little brown bat *	Myotis lucifugus	Forest Edge
Long-tailed weasel *	Mustela frenata	Various
Marten *	Martes americana	Coniferous Forest
Masked shrew	Sorex cinereus	Non-Forest
Mink *	Mustela vison	Streams
Montane vole	Microtus montanus	Non-Forest
Moose G	Alces alces	Various
Mule deer G	Odocoileus hemionus	Various
Northern pocket gopher	Thomomys talpoides	Non-Forest
Pine squirrel	Tamiasciurus hudsonicus	Coniferous Forest
Porcupine	Erethizon dorsatum	Coniferous Forest
Red-backed vole	Clethrionomys gapperi	Forest & Shrub Community
Short-tailed weasel *	Mustela erminea	Various
Silver-haired bat *	Lasionycteris noctivagans	Forest Edge
Snowshoe hare	Lepus americanus	Coniferous Forest
Striped skunk *	Mephitis mephitis	Various
Uinta ground squirrel	Spermophilus armatus	Shrub-Grassland
Vagrant shrew *	Sorex vagrans	Forest
Western jumping mouse	Zapus princeps	Non-Forest
Yellow-bellied marmot	Marmota flaviventris	Non-Forest
Yellow pine chipmunk	Eutamias amoenus	Forest Edge

G - legal game animal
* - expected, but not observed by sight or spoor on primary study area.
† - observed by sight in Cabin Creek and Tepee Creek basins.

TABLE 2

Hebgen Area Species List
Land Birds, Non-game and Non-Prey

Common name	Specific name	Occurrence
Audubon's warbler	*Dendroica auduboni*	Deciduous Forest
Barn swallow	*Hirundo rustica*	
Black-billed magpie	*Pica pica*	Various
Brewer's blackbird	*Euphagus cyanocephalus*	Grassland
Brewer's sparrow	*Spizella breweri*	Sagebrush
Brown creeper	*Certhia familiaris*	Forest
Brown-headed cowbird	*Molothrus ater*	Grassland
Calliope hummingbird	*Stellula calliope*	Willow-Deciduous Forest
Cassin's finch	*Carpodacus cassinii*	Conferous Forest
Chipping sparrow	*Spizella passerina*	Coniferous Forest
Cliff swallow	*Petrochelidon pyrrhonota*	Streams
Common crow	*Corvus brachyrhynchos*	Various
Common nighthawk	*Chordeiles minor*	Grassland
Common raven	*Corvus corax*	Various
Dipper	*Cinclus mexicanus*	Streams
Downy woodpecker	*Dendrocopos pubescens*	Forest
Eastern kingbird	*Tyrannus tyrannus*	Non-Forest
Evening grosbeak	*Hesperiphora vespertina*	Forest
Flycatchers	*Empidonax* spp.	Various
Gray jay	*Perisoreus canadensis*	Various
Hairy woodpecker	*Dendrocopos villosus*	Forest
Hermit thrush	*Hylocichla guttata*	Forest
Horned lark	*Eremophila alpestris*	Grassland
House wren	*Troglodytes aedon*	Shrubland
Lewis' woodpecker	*Asyndesmus lewis*	Forest
Loggerhead shrike	*Lanius ludovicianus*	Various
MacGillivray's warbler	*Oporornis tolmiei*	Forest
Magnolia warbler	*Dendroica magnolia*	Forest
Mountain bluebird	*Siala currucoides*	Grassland
Mountain chickadee	*Parus gambeli*	Forest
Mourning dove	*Zenaidura macroura*	Forest Edge
Oregon junco	*Junco oreganus*	Forest
Pine siskin	*Spinus pinus*	Forest
Red-breasted nuthatch	*Sitta canadensis*	Forest
Red-shafted flicker	*Colaptes cafer*	Various
Robin	*Turdus migratorius*	Various
Ruby-crowned kinglet	*Regulus calendula*	Forest
Song sparrow	*Melospiza melodia*	Shrubland
Steller's jay	*Cyanocitta stelleri*	Forest
Townsend's solitaire	*Myadestes townsendi*	Grassland
Townsend's warbler	*Dendroica townsendi*	Forest
Tree sparrow	*Spizella arborea*	Shrubland
Veery	*Hylocichla fuscescens*	Shrubland
Vesper sparrow	*Pooecetes gramineus*	Grassland
Violet-green swallow	*Tachycineta thalassina*	Deciduous Forest

Common name	Specific name	Occurrence
Warbling vireo	Vireo gilvus	Forest
Western meadowlark	Sturnella neglecta	Non-Forest
Western tanager	Piranga ludoviciana	Forest
Western wood peewee	Contopus soridulus	Forest Edge
White-crowned sparrow	Zonotrichia leucophrys	Forest Edge
Winter wren	Troglodytes troglodytes	Forest-Shrubland
Yellow warbler	Dendroca petechia	Shrubland
Yellow-bellied sapsucker	Sphyrapicus varius	Forest

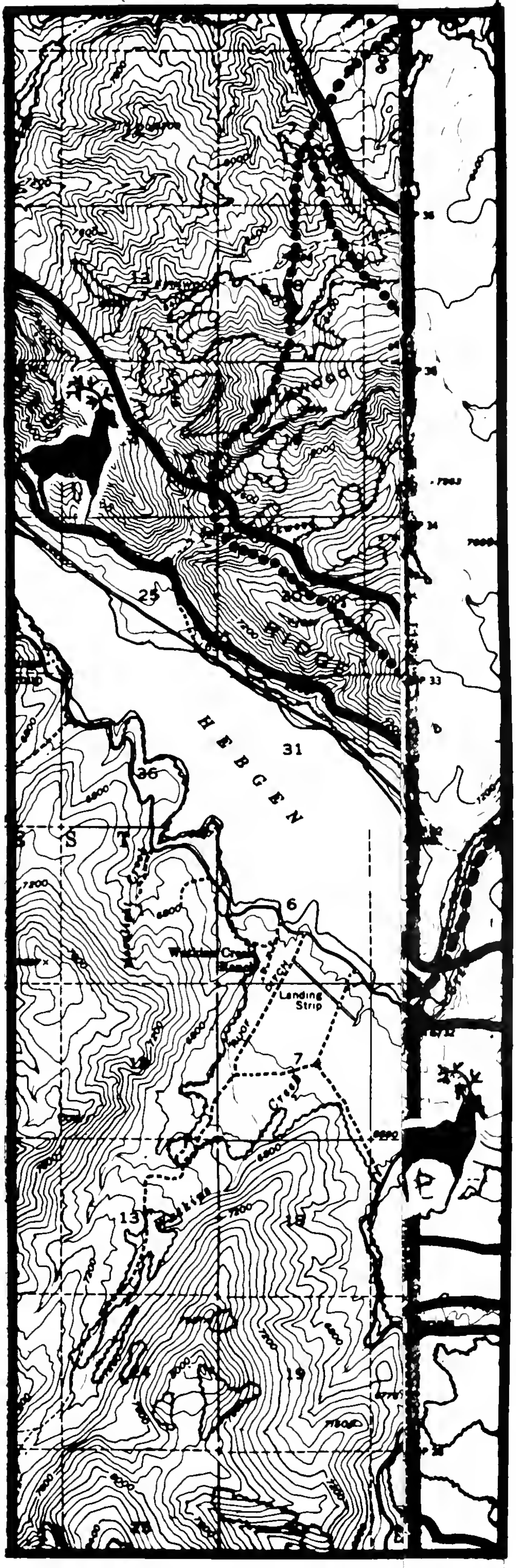
Note-all species listed above were observed in the Red Canyon Creek areas by the researcher. Undoubtedly other species are resident or migratory.

TABLE 3

Hebgen Area Species List
Birds of Game & Prey

Common name	Specific name	Occurrence
American widgeon G	*Mareca americana*	Lakeshore
Bald eagle	*Haliaeetus leucocephalus*	Lake
Blue grouse G	*Dendragapus obscurus*	Coniferous Forest-Grassland
Canada goose G	*Branta canadensis*	Lakeshore
Gadwall G	*Anas strepera*	Lakeshore
Golden eagle	*Aquila chrysaetos*	Various
Goshawk	*Accipiter gentilis*	Coniferous Forest
Great gray owl *	*Strix nebulosa*	Forest
Great horned owl	*Bubo virginianus*	Forest
Green-winged teal G	*Anas carolensis*	Lakeshore
Lesser sandhill crane G	*Grus canadensis*	Various
Mallard G	*Anas platyrhynchus*	Lakeshore
Marsh hawk	*Circus cyaneus*	Non-Forest
Osprey	*Pandion haliaetus*	Lake
Pintail G	*Anus acuta*	Lakeshore
Red-tailed hawk	*Buteo jamaicensis*	Non-Forest
Rough-legged hawk	*Buteo lagopus*	Non-Forest
Ruffed grouse G	*Bonasa umbellus*	Deciduous & Coniferous Forest
Sharp-shinned hawk	*Accipiter striatus*	Forest
Sparrow hawk	*Falco sparverius*	Non-Forest
Swainson's hawk	*Buteo swainsoni*	Non-Forest

G - legal game animal, not necessarily legal in this area of state.
* - expected but not observed by sight or spoor on primary study area.



ENVIRONMENTAL SUMMARY
SECONDARY STUDY AREA

WILDLIFE

INVENTORY

LEGEND

MOOSE WINTER RANGE

ELK WINTER RANGE

ELK MIGRATION ROUTE

MOOSE MIGRATION ROUTE

WATER FOWL NESTING AREA

GRIZZLY BEAR RANGE

ELK SUMMER RANGE

MOOSE SUMMER RANGE

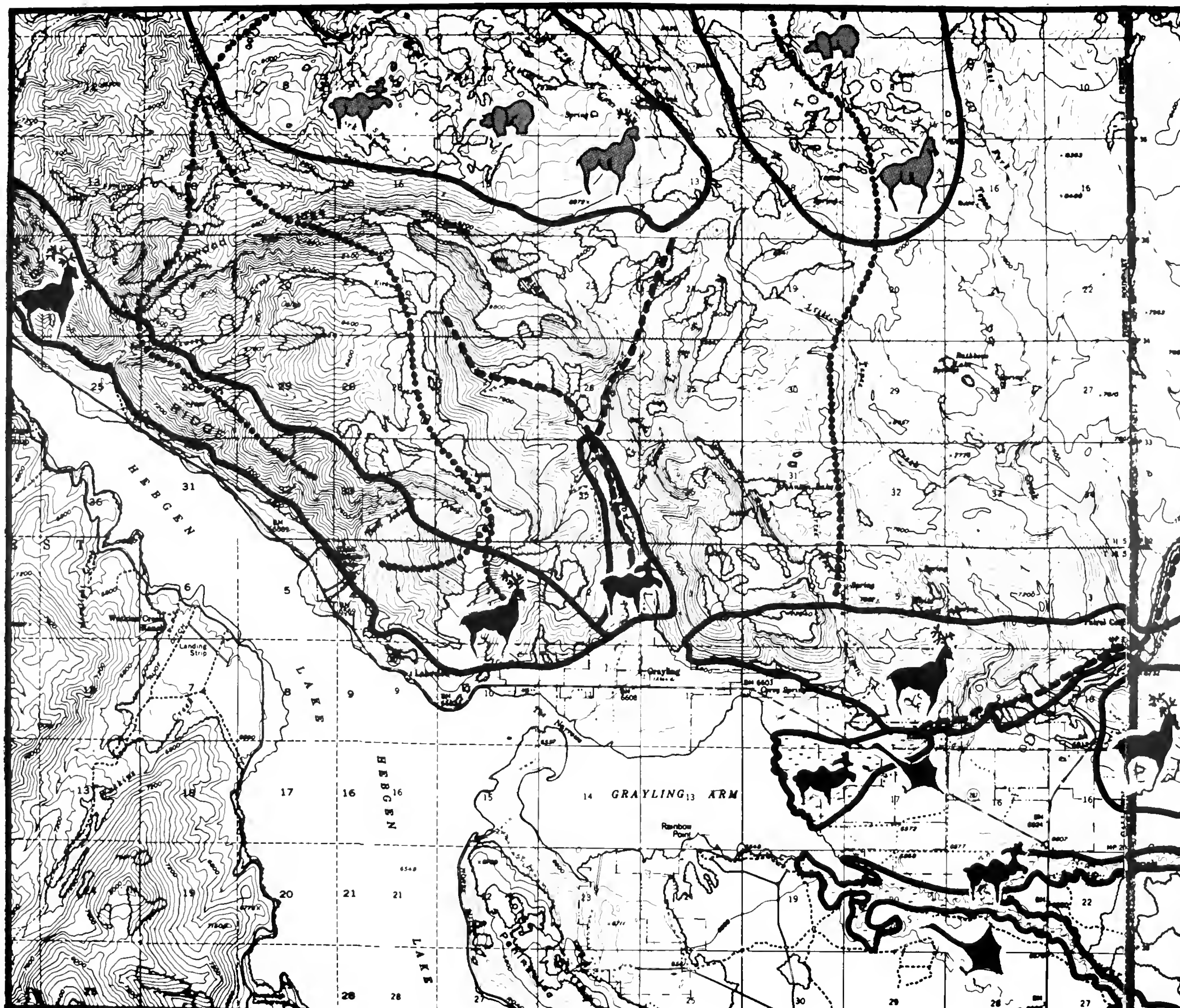
SKI YELLOWSTONE

SKI YELLOWSTONE INC.
WEST YELLOWSTONE, MONTANA

SCALE 1:62500

0 5000 10,000 FEET

0 1 2 MILES



ENVIRONMENTAL SUMMARY
SECONDARY STUDY AREA

WILDLIFE

INVENTORY

LEGEND

- MOOSE WINTER RANGE
- ELK WINTER RANGE
- ELK MIGRATION ROUTE
- MOOSE MIGRATION ROUTE
- WATER FOWL NESTING AREA
- GRIZZLY BEAR RANGE
- ELK SUMMER RANGE
- MOOSE SUMMER RANGE

SKI YELLOWSTONE

SKI YELLOWSTONE INC.
WEST YELLOWSTONE, MONTANA

SCALE 1:62500

0 5000 10,000 FEET

0 1 2 MILES

ENVIRONMENTAL SUMMARY

PRIMARY STUDY AREA

PLANT AND ANIMAL ECOLOGY

DEVELOPMENT SENSITIVITY ZONES

BY BRENT M. HAGLUND

SENSITIVITY ZONES...

- ELK WINTER RANGE
- MOOSE WINTER RANGE
- SPARSE OR CLIFF TYPE VEGETATION
- ELK CALVING AREA
- RAPTOR NEST SITE
- WINDFALL ZONE
- 3·4 SHORELINE OR STREAM VEGETATION

DEGREE OF SENSITIVITY...

- POTENTIAL LONG-TERM SEVERE IMPACT
- POTENTIAL LONG-TERM MODERATE IMPACT
- POTENTIAL SIGNIFICANT SHORT-TERM IMPACT

SKI YELLOWSTONE

SKI YELLOWSTONE INC.

WEST YELLOWSTONE, MONTANA

SCALE 1" 2000'

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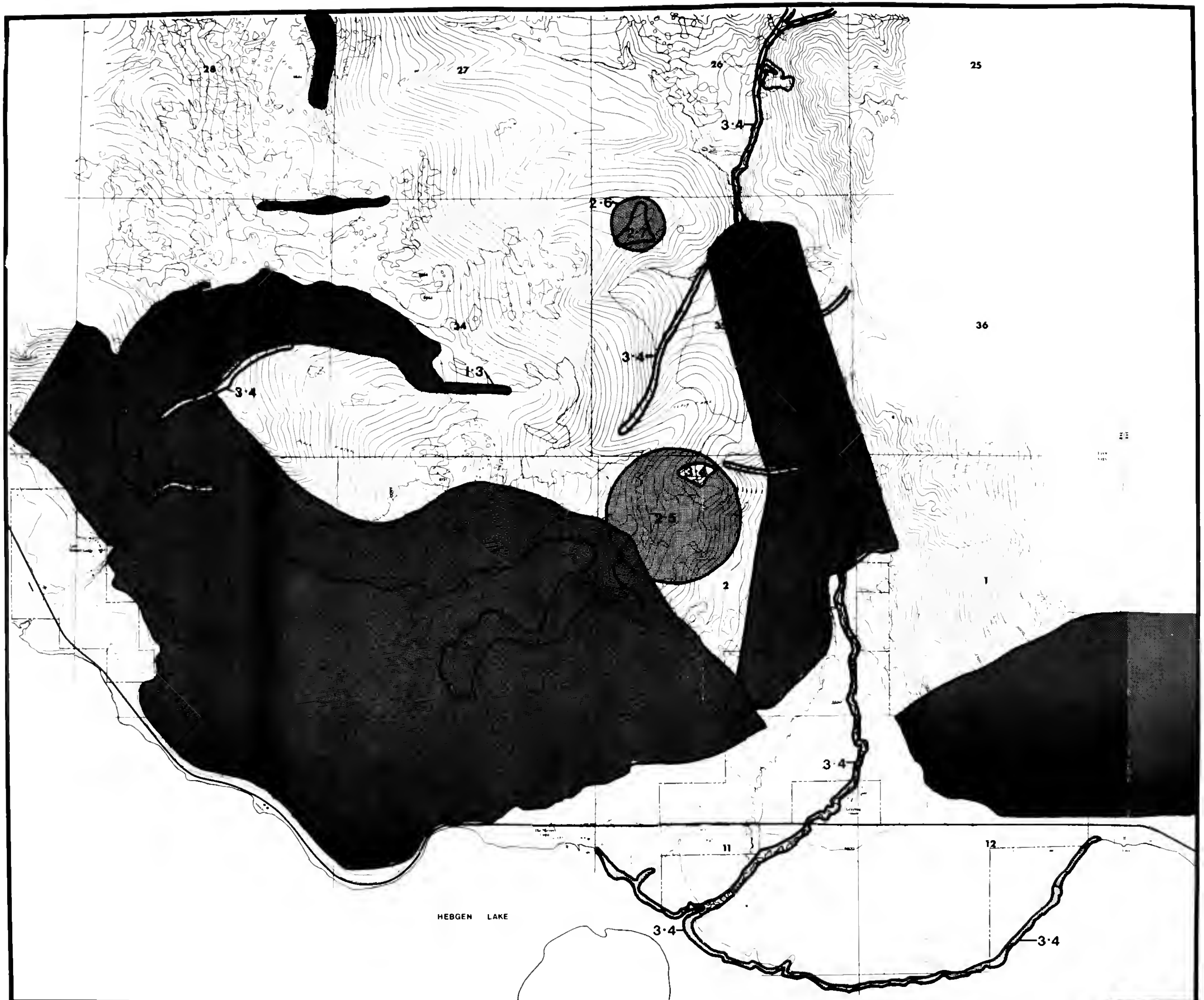
SKI YELLOWSTONE

SKI YELLOWSTONE INC.

WEST YELLOWSTONE, MONTANA

SCALE 1" 2000'



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- SPARSE OR CLIFF TYPE VEGETATION
- 2·5 ELK CALVING AREA
- 2·6 RAPTOR NEST SITE
- 2·7 WINDFALL ZONE
- 3·4 SHORELINE OR STREAM VEGETATION

DEGREE OF SENSITIVITY...

- POTENTIAL LONG-TERM SEVERE IMPACT
- POTENTIAL LONG-TERM MODERATE IMPACT
- POTENTIAL SIGNIFICANT SHORT-TERM IMPACT

SKI YELLOWSTONE

SKI YELLOWSTONE INC.

WEST YELLOWSTONE, MONTANA

SCALE 1" 2000'

ARCHAEOLOGICAL AND HISTORIC RESOURCES: SUMMARY

Leslie B. Davis

INTRODUCTION

An archaeological survey of the Red Canyon area in Gallatin County, Montana, was performed from June 15 through July 15, 1973, as part of an environmental resource inventory initiated by Ski Yellowstone, Inc. This company plans to develop areas in Red Canyon and on the Red Canyon Creek alluvial fan near the present north shore of Hebgen Lake. Ski facilities are projected for the east facing slopes of Hebgen Mountain to the west of Red Canyon Creek. Development plans provide for ski lifts, a mountain restaurant, two villages, campgrounds, parking lots and several kinds of recreational facilities in anticipation of year round use by the public.

The properties surveyed in the On-Site part of the project covered lands owned primarily by Ski Yellowstone, Inc., and by the United States, the latter of which are administered as a part of the Gallatin National Forest by the Forest Service.

The archaeological survey was conducted with dual objectives. First, an exhaustive on-the-ground reconnaisance was to be carried out to identify all possible locations of prehistoric and historic activity present in the project area. Second, the developed information was to be translated into a form consistent with the needs of the developers and the requirements of systematic planning (Figures 2 and 3). The company was to be advised of all considerations of site location and significance that might conceivably affect decision making and thereby the future of prehistoric and historic resources identified in the area.

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THE SETTING

Red Canyon is a north-south oriented canyon located within the southern extremities of the Madison Range in south-central Montana. The Canyon floor varies in elevation from 6640 to 7200 feet. The Canyon extends back into the Madison Range about 2.5 miles. It is flanked on the west by a ridge that averages well over 8600 feet in elevation. Hebgen Peak (8721 feet) is located at the southern end of this ridge. Graycroft Ridge lies to the east where it separates the Red Canyon Creek and Grayling drainages. Kirkwood Ridge bounds the Canyon partly on its northern end.

The present channel of Red Canyon Creek is about four feet wide, although considerable seasonal fluctuation in load does occur. Red Canyon Creek drains into Hebgen Lake. However, prior to the construction of Hebgen Dam in 1906, it flowed into the stream formed by the conjunction of Grayling and Duck Creeks. The resulting drainage traveled for about four miles before its confluence with the Madison River to the west (Figs. 1 and 2).

Except during intervals of peak runoff, Red Canyon Creek is a relatively low energy stream that has, over time, meandered across the narrow Canyon floor. Several small terraces remnant from these meanderings occur in the Canyon along previous as well as present stream channels. The age and persistence of these terraces is of archaeological interest. Data resulting from the hydration dating of archaeological obsidian specimens recovered from certain of the terraces may eventually permit the correlation between time and terrace formation (Table 5). The most immediate importance of the terraces is their suitability as places of recurrent habitation in prehistoric and recent historic times (Figs. 1 and 2).

PREVIOUS ARCHAEOLOGICAL OBSERVATIONS IN THE STUDY AREA

The earliest available mention of prehistoric evidence located in the On-Site study area was recorded by Wayne Replogle, Jr. and published in 1956. Fieldwork undertaken in the 1940's to re-locate the famed Bannock Indian trails produced the information. Replogle (1956:22) comments:

> "Once at Horse Butte the [Bannock] Trail branches, either trail following a general course to the north. One branch was chosen for use in good weather, the other for bad weather. The near and short trail passes east of the butte and goes along the open slopes toward the valley of Duck Creek south of the present Hamilton's ranch. The second branch follows down the Madison (now covered by Hebgen Lake) west and north of the butte to the Great Spring, a great campground according to Billy 'Pea Soup' Myers. The Great Spring, now known as Cory Spring, is at the site of the present ranchhouse of the Armstrong ranch on Montana State Highway No. 1, 8 miles north and 2 miles west of the present West Yellowstone.

> The time element played an important part in Indian travel only so far as to assure that he reached camping spots of preference fairly early in the day, with good country for grazing and plenty of timber for fuel. The Great Spring offered the most likely spot for the meeting of large groups throughout the entire course of the Trail. Many relics of aboriginal antiquity have been found here, indicating the value of the spot as a ceremonial ground, a place with plenty of water, wood and food, affording an opportunity to celebrate the oncoming hunt and the trip through the country of mystery, Yellowstone."

Davis and John Darroch visited the Corey Springs site (24GA326) on the very windy day of May 10, 1973, while making an orientation trip to the project area. At that time, the Hebgen Lake water level was beginning to raise from a low level. Four piles of fire broken rock that represented cooking or baking hearths were in evidence on the exposed shore. In and around these structures were scattered large quantities of lithic debris (Table 4), butchered and unbutchered mammal bones, scrapers and projectile points. The materials recovered agree generally with the types of specimens collected by Lew Napton (1966) during an archaeological survey of the Gallatin Valley and Canyon that extended to the northern border of Yellowstone National Park.

Hebgen Lake was drained during the summer of 1960 to permit repairs to Hebgen Dam. The Dam had been damaged August 17, 1959, by an earthquake. An independent geologist, F.W. Woodward of Billings, reported as a consequence of his inspection of the lake floor the presence of "fire pits of human origin" (Conner 1960). Archaeological evidence was found between the normal shoreline and Grayling Creek, an area that is usually submerged along the Narrows (S1/2 Secs. 11 and 12, T12S, R4E). The features, artifacts and waste flakes were observed eroding from the alluvium at depths varying from three to four feet below surface. Material was exposed along the beach and in the vicinity of the dock area to the west of Red Canyon Creek. Prehistoric evidence was being exposed persistently by wave action from the northwest. Materials were distributed on both the west and east aspects of the outlet of Red Canyon Creek.

A subsequent memo by Conner (1961) records ancillary facts of importance to an understanding of archaeological deposits extant in the Red Canyon Creek alluvial fan:

> "No Indian artifacts were found in the area of new sedimentation. About 100 feet to the side of the stream channel [Red Canyon Creek] he [Woodward] found gullies, the sides of which contained exposed, disintegrating bone fragments, tooth enamel and burned stones. The depth of the exposed bone was an estimated 6 or 7 feet below the piles of rock lying on the alluvial fan. The land drops

> only slightly toward the Greyling (sic) Creek into which Red Canyon Creek empties, so the fact that the exposed bone was closer to Greyling (sic) Creek than the rock piles probably indicates greater antiquity and true depth for the exposed bone than for the rock piles."

The type and quality of survey information made available by the timely actions of Woodward, Conner and amateur and professional archaeologists from Montana State University and the University of Montana could not have been developed under the currently stable condition of Hebgen Lake. That single, privileged glimpse into the post-inundation condition of the eroded alluvial deposits that underlie the lake provided valuable, if presently unverifiable, evidence of early human activity in this part of the Madison River basin.

Routine archaeological surface reconnaissance has been performed in immediately impinging parts of the Northern Rocky Mountain province of southern Montana, namely investigations in the Gallatin Canyon by Napton (1966), in the Upper Yellowstone River valley by George Arthur (1966, 1968) and Larry Lahren (1971) and in Yellowstone National Park by Jacob Hoffman (1961), Dee Taylor (1964) and Aubrey Haines (1963, 1965). These studies provide a backdrop against which the adequacy of archaeological data developed during the 1973 site reconnaisance of the Red Canyon, Red Canyon Creek, Red Canyon Creek fan and Off-Site localities can be measured.

The aforementioned investigations depended largely on surface collecting, but they led to a similar conclusion; namely, that these localities had experienced more or less continuous, if seasonally intermittent, habitation for at least from 10,000 to 12,000 years.

THE SURVEY

The foot reconnaisance was conducted within the On-Site impact area (Red Canyon Creek, Hebgen Peak, the Red Canyon Creek alluvial fan and the Hebgen Lake shore) by Charles Zeier, field supervisor, and Robert Peterson, advanced students majoring in Anthropology at Montana State University. Secondary efforts were extended by automobile around the south side of Hebgen Lake and by foot along the east perimeter of the Off-Site impact area.

The initial effort by the survey crew took place in the Canyon, with subsequent forays onto the fan. After the crew had identified sites and potential site areas, Davis brought his Summer Field Archaeology class of nine Montana State University students to the project area to dig for sub-surface evidence. The class arrived July 9 and concluded the testing and excavation program on July 13, having contributed one additional man-month of labor to the project gratis. This work demonstrated clearly the necessity of supplementing surface surveys with deep testing in selected areas. The nature of erosion by water, rodent and foot and vehicle traffic as agencies of exposure does restrict the kinds of buried materials that are exposed. Surface exposed evidence had led to an erroneous conclusion, namely that the only prehistoric evidence in the

Canyon and upper part of the fan occurred in very shallow context and was irretrievably mixed by rodent burrowing. Deep excavation revealed the presence of a preserved fireplace still filled with charcoal. Stratified deposits also exist that have not been confused by the mixing effect of rodent burrowing.

The foot survey eventually produced evidence of eight On-Site and five Off-Site sites of prehistoric origin and four On-Site sites of a recent historic nature. Another 11 locations are designated as find spots. Several site leads were developed as a consequence of visiting with private individuals who are knowledgeable about the area; not all leads could be checked out thoroughly during the brief span of the survey.

SITE DESCRIPTIONS

Descriptive and interpretive information about each of the 12 prehistoric and four historic sites studied during the survey are summarized in Tables 1, 2 and 3 for convenient reference. The following general descriptions characterize the sites succinctly. On-Site Prehistoric Sites are discussed first, followed by Off-Site Prehistoric Sites and then On-Site Historic Sites.

Y-Bother Site (24GA698):

Located on a relatively large alluvial-colluvial terrace at the end of the main arm of Red Canyon, this site constitutes the most extensively occupied single site in the On-Site area. Large quantities of waste flakes were found in the road, in mole backdirt and in test pits; sediments vary from 15 to 100 cm. in depth. No time culture diagnostic tools were recovered, but further work may yield that type of information. One hundred and four waste flakes were collected from this site (Table 4). Small bone slivers, unidentifiable as to specific bone element and species, were found during the subsurface exploration. The site is located on Forest Service property.

Peterson Site (24GA699):

Attention was drawn to the Peterson site by a topographic depression in proximity to an abondoned channel of Red Canyon Creek and by obsidian waste flakes exposed along the eroded edge of the channel bank and in a worn foot/game trail. Thirteen objects of archaeological interest were found, 10 of which were waste flakes and one of which was an edge modified flake tool found at 150 cm. below surface in Test 2. A split mammal rib that had been polished by use as a stone working tool was found at 106 cm. in Test 1 (Fig. 13) above which, at 50 cm., was located a charcoal-filled, stone encircled, shallow basin hearth (Fig. 5). The two separated test pits occupied a very small percentage of the available surface area; thus, the remaining buried deposits are probably distributed throughout this meander depression. This site is on company property.

Upper Terrace Site (24GA1133):

Just across the old stream channel and slightly upstream from the Peterson Site is a terrace that is about four feet higher in elevation (Fig. 6). Nineteen waste flakes, none of them modified, were found in the test pit that was excavated to basal gravels. No tools or features were identified. Obsidian constituted 47 percent of the lithics. This site is on company property.

Main Cabin Site (24GA1139):

The stream terrace directly behind the company cabins at the mouth of Red Canyon yielded the skeletal remains of several species of large and small mammals along erosion cuts and in two separated test pits. No lithics were found. The extensive open area immediately in front of the cabins was also tested with no success. Rodent burrows, though numerous, yielded no prehistoric materials. This site is on company property.

Grayling Road Site (24GA1134):

In the ruts of the old Grayling road, a few waste flakes and a knife made of jasper were found; the knife (Fig. 13) was picked up by John Montagne during his work in the area. No concentration of materials was located even though the road approaches very near an old channel of Red Canyon Creek. This site is on company property.

Hebgen Mountain Site (24GA1135):

In a small basin just to the east of the summit of Hebgen peak and on around the north face of the peak, small nodules of a brownish-grey chert are weathering out of a Madison limestone matrix. The nodules are generally smaller than one cubic inch in volume. The quality and color range of the chert matches that of chert recovered at the Hill 8625 Site mentioned below. This outcrop at 8700 feet may be an extension of the Hill 8625 outcrop that is exposed at 8500 feet. The chert exfoliates but fragments appear natural and there is no compelling evidence that the exposure was utilized as a stone quarrying source. An exhaustive search of the area may turn up exposures that were exploited. This type of chert does appear in artifact collections from the area. One large obsidian flake (Table 5, NWP Project #D2359) was recovered from the surface near the chert exposure. This site is on Forest Service property.

Hill 8625 Site (24GA1136):

This is a potential quarry of a brownish-grey chert. It is located on the east slope of Hebgen peak about 1.75 miles north of Hebgen peak. The chert occurs as layers within a matrix of Madison limestone. These layers extend discontinously for about 200 yards. At either end, the layers diminish and small chert nodules continue on for short distances. The layers have a maximum thickness of two inches; they exhibit extensive internal fracturing that

would limit the usefulness of the stone as artifact source material. This site is on Forest Service property.

Corey Springs Site (24GA326):

Located almost immediately below the highway just on the eastern edge of the On-Site development area, the Corey Springs site consists of beach gravel terrace remnants that contain considerable evidence of heavy prehistoric use of the spring area. Each annual cycle of beach reworking and progressive land surface erosion yields more materials. The nature of these materials was discussed in a previous section. Our early spring visit to the site yielded many obsidian waste flakes and several projectile points typical of the Late Prehistoric Period (Fig. 13). The four stone-filled hearths should be excavated at low water, since they are being dispersed gradually by the deflating action of the water. This site is on private property.

Dandelion Meadow Site (24GA696):

This site is located along the small drainage that originates in Johnson's Lake, a small lake just east of the Graycroft Ridge. This drainage meanders across the quarter mile square "Dandelion Meadow". Sediments range from three to six feet in depth. Lithic debris was found scattered where rodent activity had exposed the buried deposits (Table 4). This site is on Forest Service property.

Bumblebee Meadow Site (24GA697):

This location is just downstream from Dandelion Meadow. The two sites are separated by a constriction in the canyon walls that bound them on the east and west. Maximum deposition here is only about three feet. Thinly scattered lithic debris was the only evidence of prehistoric culture evident here (Table 4). This site is on Forest Service property.

Lake Shore Site (24GA700):

This site was on a terrace about 15 feet above the south fork of the Madison River before 1906. Today, it is about one mile back in from the South Fork Arm, about two feet above the maximum lake level. It has suffered surface denudation by wave erosion. Archaeological materials are found in the gravels that underlie the culture-bearing sediments that were originally two to three feet in depth. This site is on Forest Service property.

Narrows Spit Site (24GA1131):

In Hebgen Lake there is a spit of land that projects into the lake as an extension of Horse Butte. This spit separates the Grayling Arm from the rest of the Lake. Archaeological lithics were found along the eroded edges of the spit. Prior to 1906, the spit was a small hill about 60 feet above stream level; this hill was the northeast extension of the Bull Lake glacial end

moraine of which Horse Butte is the main unit. The Narrows Spit has ethnographic significance since the Bannock Indian Trail passed across it below the present water level. Forty-eight pieces of lithic debris were found during the surface investigation. Fifty-eight percent of the sample is comprised of ignimbrite. Large quantities of ignimbrite were apparently transported by glaciers from the rhyolite plateau in Yellowstone to the east. Large quantities of ignimbrite fractured by geological action also litter the spit area. This site is on Forest Service property.

Rainbow Point Site (24GA1132):

Rainbow Point and the lake shore to the west is designated as a single site, despite its extensiveness. Local collections from this site reveal surprising quantities of prehistoric remains in view of the scarcity of evidence revealed during the surface reconnaisance. In the spring and in the late autumn when the Lake is down, surface collecting is most productive. At that time, that portion of the Lake bottom that was once a gentle slope adjacent to the Madison River is exposed. Part of the site may still be contained within sediments that have not been eroded. This site is on both private and Forest Service property.

Old Cabin Site (24GA695):

Located in a small draw that leads into the east face of Hebgen Peak, about 200 feet from the present channel of Red Canyon Creek, is a historic site. Near the north slope of the draw, a partial foundation extends outward in a contour fashion. It appears that this structure was a levelling platform for some kind of super structure of unkown type. The top of a wood stove, glass and a belt buckle were also observed. This site is on Forest Service property.

Old Cabin II Site (24GA1137):

This site has a wealth of historic objects in evidence around the main wooden structure. A dump is located to the east of the cabin along the slope leading to Red Canyon Creek. Only the foundation remains at the cabin site proper. This site is on Forest Service property.

Old Barn Site (24GA1138):

This historic site appears to be a barn or barn-like structure. Little evidence other than the log structure remains. This site is on Forest Service property.

Grayling Townsite (24GA1140):

Appendix I details the characteristics and significance of the remaining structures in the Grayling Townsite.

FIND SPOT DESCRIPTIONS

The distribution of the 11 identified "find spots" is mapped in Figs. 1, 2 and 3. Fig. 17 displays the mammal bone collection recovered during the survey. Find spots are designated as A through K:

A. Faunal remains were found along the west fork of Red Canyon Creek at the base of Hill 8625.

B. Faunal remains and sparse lithic debris were found in the area just to the west of 24GA698.

C. The Coal Canyon road collecting area yielded faunal bone from the ruts of the road.

D. Collections along Red Canyon Creek on the Red Canyon fan included only faunal bone.

E. Faunal remains were located on the Red Canyon Creek fan.

F. Faunal remains were found along the present Lake shore.

G. Faunal remains were located along the drainage out of Johnson's Lake.

H. The Watkins Creek collection area contained thinly distributed lithic and faunal remains.

I. Several faunal finds were made in Coal Canyon clearing.

J. A few faunal remains were found in the vicinity of 24GA695.

K. A nearly complete skeleton of bison was found in a terrace between 24GA699 and 24GA1133.

LOCAL ARTIFACT COLLECTIONS: THEIR PLACE IN REGIONAL PREHISTORY

Private persons who collect artifacts do so under circumstances of leisure and opportunity usually denied to formal archaeological endeavors. The Hebgen-Red Canyon Creek experience was no exception. The majority of artifacts that came to our attention were collected or otherwise recorded prior to the formal site reconnaisance. The majority of the collected objects reported here were disturbed from their natural context by erosion resulting from the inpoundment of waters behind Hebgen Dam. None of the specimens were actually dug by the collectors. Such collections can be highly informative and useful in evaluating ahe representativeness of site survey data. The Stovall (Figs. 8, 9, 10 and 11) and Woodard (Fig. 14) collections are especially noteworthy in this respect.

REGIONAL CULTURAL SEQUENCE AND CHRONOLOGY

Archaeologists concerned about the prehistory of the Northwestern Plains archaeological region recognize three primary divisions of cultural type and geological time. For purposes of organization and discussion, Mulloy's (1958) outline of Prehistoric Periods, as modified and elaborated by Reeves (1969), is employed as a classificatory device:

<u>Early Prehistoric Period (ca. 15,000-13,000 to 5500 B.C.)</u>

Clovis Complex (10,000 to 9000 B.C.)

Folsom-Midland Complex (9000 to 8500 B.C.)

Agate Basin-Hell Gap Complex (8500 to 7500 B.C.)

Alberta-Cody Complex (7500 to 6500 B.C.)

Lusk and Frederick Complexes (6500 to 5500 B.C.)

<u>Middle Prehistoric Period (ca. 5500 B.C. to A.D. 200)</u>

Mummy Cave Complex (5500 to 3500 B.C.)

Oxbow Complex (3500 to 2500 B.C.)

McKean Phase (2500 to 1500 B.C.)

Hanna Phase (1500 to 1000 B.C.)

Pelican Lake Phase (1000 B.C. to A.D. 200)

<u>Late Prehistoric Period (ca. A.D. 200 to A.D. 1800)</u>

Avonlea Phase (A. D. 200 to A. D. 700)

Besant Phase (A. D. 200 to A. D. 750)

Old Women's Phase (A. D. 750 to A. D. 1800)

Prehistory actually ends in this area with the arrival of the Lewis and Clark Expedition in 1805-1806. Ethnographic records developed by anthropologists, and on occasion by historians, bridge the gap between prehistoric and historic lifeway reconstructions.

It is important to note that essentially all of the prehistoric cultures that frequented the study area were collectors and gatherers, dependent primarily upon big game hunting and secondarily upon the gatherings of wild plants for subsistence.

We recognize certain artifacts used in the killing of big game as "fossil indices", namely, projectile points. Each point "type" is diagnostic of a specific "archaeological culture."

THE RAINBOW POINT SITE (STOVALL) COLLECTION

Mrs. Stovall and members of her family have made surface collections from along the lakeshore and at collecting areas in the vicinity near Point of Rocks and Divide Lake for a number of years. Fig. 8 displays the majority of the Stovall projectile points (excluding those of obsidian that can be seen in Fig. 10). Illustrated are 13 points that represent the Agate Basin Complex (Nos. 10 and 11), the Alberta-Cody Complex (Eden point) (No. 9), the McKean Phase (No. 8), the Hanna Phase (Nos. 4, 5, 6 and 7), the Mummy Cave Complex (Bitterroot points) (Nos. 2 and 3), and the Pelican Lake Phase (No. 1). Nos. 12 and 13 are aberrant lanceolate points that appear to derive from the Early Period, but which are not classifiable otherwise.

Figs. 9 and 10 illustrate the main types of bifacially modified tools that served as knives. Knives vary principally in length-width ratio. Absolute weight is regarded as an indication of whether a knife was used for heavy duty or light duty butchering. Specific knife forms cannot be attributed to specific cultures in terms of shape alone. Only one of the knives appears to have been hafted (Fig. 9, No. 2).

Fig. 11 displays end scraper variations. Both hafted and non-hafted forms are present. Scrapers are used to remove fat and membrane in the preparation of hides for tanning.

The Stovall collection includes large quantities of lithic waste in addition to the artifacts. Although the entire collection was not analyzed, it did appear that the types of stone and their relative frequencies of occurrence were in essential agreement with the lithic utiliztion pattern determined by the Hebgen-Red Canyon Creek survey (Table 4).

THE COREY SPRINGS COLLECTIONS

Specimens available at Corey Springs have been pirated for many years, so that our present control of information must necessarily be superficial. Napton (1966) recorded the occurrence of projectily points, knives, scrapers, choppers, and edge ground cobbles, among other items. Fig. 12 (extracted from Napton, Fig. 24) shows Agate Basin (No. 9), McKean (No. 1), Pelican Lake (Nos. 2 and 4), Besant (No.7), and Old Women's (Nos. 3 and 6) points. Nos. 5 and 8 cannot be classified with any reliability.

The small collection made by Davis and Darroch in 1973 (Fig. 13) includes two Old Women's points (Nos. 1 and 2) made from chert, a quartzite chopper, (No. 6) a basalt knife (No. 7), and an end scraper fashioned from opalized wood (No. 8).

Large quantities of lithic debris, bone fragments and fire cracked rocks litter the Corey Springs beach at low water. The presence of four mounds of fire cracked rock was mentioned previously.

THE RED CANYON FAN-NARROWS (WOODARD/MONTANA STATE UNIVERSITY) COLLECTIONS

Our foot survey along the north side of the Narrows along the eroding edge of the Red Canyon fan produced only mammal bone assumed to represent human use (Fig. 3). Fig. 16 shows the degree of beach exposure in 1960 when the Lake level was lowered for dam repairs. Fig. 15 is of a mound of fire cracked rock extant from an early campsite. (Note: Figs. 15 and 16 are black and white renderings of Woodard's slides by S.W. Conner and blown up for first illustration here.) This hearth is identical to those observed by Davis and Darroch in 1973 at Corey Springs.

Fig. 14 is a composite of Woodard's photos (Nos. 2, 4, 5, 7, 8, 9, 10 and 11) and one of points taken by the crew from Montana State University that visited the Narrows Site (24GA101) in 1960 (Nos. 1, 3, 6, 12, 13, 14 and 15).

Archaeological cultures represented by the points include Bitterroot (No. 13), Oxbow (No. 12), McKean (Nos. 10 and 11), Hanna (No. 9), Pelican Lake (Nos. 6, 7 and 8), Avonlea (Nos. 4 and 5), and Old Women's (Nos. 1, 2 and 3). Fragmentary knives, points, scrapers, a hammerstone and a possible edge ground cobble were also collected. Nos. 14 and 15 are somewhat indeterminate in type. There can, however, be little doubt that they are attributable to the Early Period. No. 15 has collateral flake scars and appears as though a flute may have been struck from its base. If that is the case (the point is not available for examination), the point is classifiable as a Clovis Complex atlatl dart point. Given the rarity of evidence for these early mammoth hunters in this area, the find could he highly signifiaant.

CONCLUSIONS

Although the available record is obviously spotty, given the fortuitous nature of artifact recovery upon which this report is largely dependent, the evidence is nevertheless persuasive. There can be little doubt that the Madison River headwaters area experienced prehistoric traffic and use comparable in intensity and duration to that of any other drainage system investigated within this sector of the Northern Rockies. The fact that the majority of the culture-bearing land surface is now inundated is sufficient to explain the apparent dearth of prehistoric evidence. Erosion-produced evidence at some distance from the inundated river and its associated terraces confirms the prediction that prehistoric land use was indeed extensive. And surface collections from locations in the drainage basin above the lake level have yielded predictable quanitites of artificial remains.

Projectile points represent the majority of archaeological cultures known for the region at large. There are certain variant forms that are difficult to classify. Early Period evidence is typically sparse but there is evidence of 60 percent of the culture complexes recognized for this Period. Virtually all of the culture complexes and phases typical of the Middle Period are represented. And the same is true of the Late Period manifestations.

The Hebgen-Red Canyon Creek development locality occupies but a small part of the terrain to which the foregoing discussion applies. The observations are more or less directly applicable, depending upon the specific location of a possible construction site.

ASSESSMENT OF SIGNIFICANCE AND IMPACTS

POSITIVE IMPACT

Developments such as Ski Yellowstone, Inc. can have positive effect on archaeological and historic resources. Previously little known or unknown localities subjected to preliminary resource inventories such as the one concluded here receive a beneficial estimation of their natural and cultural values. The results of such studies are in the best long term interest of society. Knowing is better than not knowing, even if the knowledge generates new conflicts between the natural and potentially developed condition.

The generally "low profile" nature of archaeological things in the Hebgen-Red Canyon Creek project area discourages the possibility of developing in-place educational and recreational exhibits at specific site locations. There is simply nothing of consequence to observe. Also, it is generally poor practice to advertise what may otherwise be better protected by non-mention. Data derived from the survey and ancillary studies can be presented in an interpretrive center or in a popular brochure advertising the wholesome benefits of the resort complex.

Sites of historic interest such as the Bannock Trail (see Replogle 1956 and Haines 1962) and Grayling Townsite (Appendix I) can be developed as roadside interpretive exhibits and as an aspect of the overall integrated recreational program envisioned by Ski Yellowstone, Inc.

The structural features of the identified historic sites (Old Cabin, Old Cabin II, Barn and the Grayling Townsite) can be recorded photographically and studied in detail on the ground. These sites could be thoroughly collected by knowledgeable, responsible persons to avoid the loss of historic items to collectors. The course of action here should be determined by someone concerned about and qualified to make such records and collections.

THE NATURE OF ARCHAEOLOGICAL RESOURCES

The destructibility of fragility of archaeological resources and their inherent internal relationships is a function largely of their accessibility. Deeply buried deposits of cultural material are threatened by such natural agencies as erosion and rodent burrowing. The integrity (degree of preservation) of deeply buried deposits is compromised by the encroachment of deep excavation activities associated with the construction of subsurface structures and facilities.

Shallowly buried evidence of prehistoric cultural activity is readily susceptible to destructive disturbance. Any degree of surface modification can effectively eliminate these highly fragile deposits.

Archaeological data are valued, secondarily to their non-renewable cultural heritage aspect, for the quality and quantity of information that can be inferred from their analysis. The significance of archaeological resources is therefore dependent upon the relative information value of materials recovered from the earth. Deep burial heightens the possibility, though it in no way guarantees the fact, that the physical relationships among the cultural objects will have been preserved in their original condition.

Evaluation of anticipated negative impacts of surface and/or sub-surface development is thus contingent upon the conditions and depth of burial and the estimated information value of evidence in any given place.

Direct evidence of prehistoric cultural activity in the Hebgen-Red Canyon Creek project area consists of perishable and non-perishable natural items that have been altered by human intervention:

1. Perishable Materials include the organic remains of mammals that were utilized primarily as food sources, i.e., complete, butchered and otherwise fragmentary bone, and tools fashioned from the bones of animals.

2. Non-Perishable Materials consist of finished tools (projectile points, knives, scrapers, drills, awls, etc.) and cores and flakes wasted during the manufacture of tools from various kinds of native stone that are amenable to stone working technology.

The only kind of prehistoric feature (immovable structure) remnant in the project area consists of fireplaces or hearths used for cooking by roasting, namely the charcoal filled, stone encircled basin-shaped hearth buried at the Peterson site and the stone filled mounds of fire broken rock located at Corey Springs and in the area reported by Woodard along the Red Canyon Creek fan to the west. No evidence of dwellings or ceremonial structures was developed. Small rockshelters at high elevation above the north end of Red Canyon were probably not habitable.

Sites of prehistoric activity are regarded in two ways. Those locations that were only very lightly indicated by "cultural bone" are considered find spots. They are indicative of human activity but their information value is very low. Those locations that yield materials in sufficient quantity and of a variety of kinds (tools, features, bone, flakes, etc., in any combination) are assigned Smithsonian Institution uniform site designation numbers that enter them into a permanent recording system. Site reports are filed with concerned federal and state agencies.

SIGNIFICANCE DETERMINATION

Find spots and designated sites were assigned significance levels according to the following general criteria (see Fig. 3):

4. Least Significance - Erosion exposed find spots indicated usually by one or more "cultural bones". (24GA1134, A through K)

3. Low Significance - Sites where the cultural evidence consists of only a few stone flakes in combination with bone fragments. Surface to shallowly buried, disturbed by rodent activity, and extensively distributed in space. (24GA1139)

2. Medium Significance - Shallowly buried, localized deposits that contain worked stone and multiple other cultural indicators, possibly some tendency toward stratification (multiple occupations overlying one another and separated by culturally sterile sediments). (24GA698, 24GA1136)

1. High Significance - Deeply buried, often stratified, concentrated deposits that contain features and/or tools that are associated. (24GA699, 24GA1133, 24GA1135, 24GA326)

Fig. 3 displays the find spots, the prehistoric sites and the historic sites that were identified by the survey and the study of existing records. The number on each of the circles indicates the level of significance assigned to that locus. (Fig. 3) The degree of actual impact will be determined by the location of specific development activities in relation to these identified locations.

HAZARD AND IMPACT ESTIMATION

The degree of anticipated negative impact attributable to project development is classified as Low (in the case of Least and Low Significance sites), as Moderate (in the case of Medium Significance sites) and High (in the case of High Significance sites) dependent upon the intensity of earth modification activity that actually occurs.

Least and Low Significance find spots and sites are considered subject to Low Impact. These locations are usually scattered thinly over extensive space. It is doubtful that the occurrences of sparse cultural debris will be obliterated entirely by surface modifying operations. If they are, the waste must be considered non-preventable.

Medium Significance sites will experience Moderate Impact in the course of surface scraping operations due to their depth of burial and the odds that their restricted location in space will be missed or consciously avoided during development. Deep excavation would eliminate the deposits if locations coincided on a one-to-one basis in space.

High Significance sites will definitely experience High Impact if deep excavation is performed where such sites are known or anticipated to exist. Terminal destruction will likely result from the ill advised deep excavation of these sites. If these sites are avoided, they are likely to escape the negative effects of traffic and erosion at its current rate.

OTHER SENSITIVE HAZARD AREAS

The survey was designed to identify specific locations of prehistoric and historic cultural activity. That objective was accomplished within the limits of the survey strategy. The work also formed several very definite impressions of materials distributed too widely in space to be truly characterized by the limiting designation of find spot or site. These generalized hazard localities on the land surface are shown in Fig. 3.

Abandoned Channels of Red Canyon Creek

Caution should be exercised when lands marked by abandoned stream channels are modified by earth moving operations. The majority of the visible channels were probably active during the 12,000 + years that the area was frequented by early hunters. Terraces along these channels probably contain evidence of those events.

The only clearly stratified cultural deposits identified during the survey were found on terraces associated with the westernmost abandoned channel at the Peterson and Upper Terrace sites (Tables 1, 2 and 3). If this channel is resurrected (a possibility mentioned by planners), the known as well as unknown cultural deposits will be endangered by the resulting inevitable erosion. For that reason alone, re-routing Red Canyon Creek into this former channel seems inadvisable.

The Headward Eroding Edge of the Red Canyon Creek Alluvial Fan

More than a half dozen individual finds of cultural bone were found along the persistently eroding southern edge of the fan across its maximum extent. It seems apparent that cultural evidence is widely, if thinly, scattered across the fan. The observations by the geologist Woodard during the unprecedented lowering of the lake in 1960 confirm this suggestion. There are obviously deeply buried cultural remains that may be of appreciable age contained

within the fan alluvium. The construction of a Lakeshore Village should be performed with this possibility in mind.

The Corey Springs Shoreline

Cultural debris is known to be distributed without interruption along the shoreline adjacent to Corey Springs, particularly to the west along the emerging aspect of Red Canyon Creek fan. The area has been a popular artifact collecting ground for at least three decades. The richness of artifactual remains on the west terrace of the main spring probably extends along the terrace under the lake and for an unknown distance along the present beach to the west. Any beachline development in this area, though none is anticipated, should take into account the known high yield of prehistoric items. The pattern localized at Corey Springs does not appear to be shared along the emergent west edge of the fan.

The Upper Surface of Hebgen Mountain

Although it was not mapped as an area of extensive sensitivity (Fig. 3), the top of Hebgen Mountain should be regarded as a possible hazard area. The location of only trace evidence and the two possible chert quarrying sites (24GA1135 and 24GA1136) in the high elevation area did not exhaust the possibility that other evidence may also be available. The area consists of bedrock overlain by a thin mantle of soil and holding vegetation. There is no likelihood of deeply buried materials, but the predicted shallow sub-surface scatter may be informative.

The Bannock Indian Trails

The course of the Bannock Indian Trails is presented in Figs. 1 and 2. The northern extremities of the Trail have been inundated. There cannot, therefore, be any protective measures taken against further wasting of the Trail itself in the On-Site development area. Stretches of the Trail are still above water south of Hebgen Lake in the Off-Site area and it is to be expected that evidence of Indian and trapper activity may be exposed from time to time along the fluctuating shoreline of the lake. Knowledge of the existence of the Trail should enrich interpretation of the roles played by the Hebgen-Red Canyon Creek landscape in earlier times. Despite the absence of definable hazards to this historic feature, some consideration should be given to acknowledging and valuing its presence.

MITIGATION OF ANTICIPATED NEGATIVE IMPACTS

The physical avoidance of all areas specified as hazardous to prehistoric and historic resources would, of course, introduce little measurable damage. The concentration of population and associated types of traffic will play subtle havoc with the shallowly buried remains but to a degree that cannot be anticipated systematically. On-Site modifications will be more detectable than Off-Site disturbance but the cumulative effect cannot be minimized.

All objects of prehistoric significance identified during the survey were recovered, thus preventing their inadvertent waste. (Note: all archaeological specimens are currently housed in the archaeological laboratories in the basement of Colter Hall at Montana State University.) Some still buried materials will be exposed gradually as a function of agencies specified previously and as accelerated by unprecedented population pressure.

It is the construction phase of the development that will produce the greatest and possibly irreversible negative impacts. The presence of a qualified archaeologist as a monitor during surface scraping operations would constitute a surveillance mechanism that would provide certain knowledge about the possible wasting effect of such activity, if any.

The monitoring of sediments removed by ditch digging equipment or moved by bulldozers or surface graders would provide a measure of protection to buried cultural materials exposed in the process. If deep excavation is scheduled at any of the designated High Impact or other constraint locations, the company should be prepared to call in an archaeologist to monitor the excavation in the event that predicted or unanticipated prehistoric evidence is encountered. Depending upon the importance of such possible finds, it may be necessary to salvage the exposed materials. If the evidence is too important to merely salvage, i.e., direct recovery from an excavated cut in the absence of a systematic effort to locate the materials in terms of their surrounding context, it may be advisable to conduct a formal and systematic dig.

In any case, communications should be established between a company representative and a professional archaeologist with an understanding that the archaeologist is on call. When schedules of surface modifying work are known in advance, the retained archaeologist should be given as much advance warning as is practicable to permit his presence as a monitor during earthmoving operations.

This type of relationship would insure a reasonable measure of protection to the company against justified criticism and to the public inheritors of the national prehistoric legacy. The well known ease with which archaeological, paleontological and recent historic remains are often wasted makes such a course of action imperative.

Public Law No. 209 (An Act for the Preservation of American Antiquities approved June 8, 1906 as 34 Statute L. 225) provides legal recourse for the unlawful appropriation, excavation, injury or destruction of any historic or prehistoric ruin or monument, or any object of antiquity, situated on lands owned or controlled by the Government of the United States. Despite the uncertainty of prosecution under this law, a measure of public reply to advertent destruction does exist.

Objects of historic and prehistoric value situated on private property can be protected if the enlightened landowner will deny access to his property for collecting purposes. He can prosecute violators of his negative sanction under the laws of trespass, given certain technical requirements in any given case.

Positive action is required if these highly fragile, all too commonly squandered resources are not to succumb by default to the carelessness of those in a position to honor and promote their existence.

CONCLUDING RECOMMENDATIONS

Table 2 details the further work recommended for each of the locations identified during the survey. No further work is recommended for the Y-Bother, Main Cabin, Grayling Road, Hebgen Mountain and Hill 8625 sites. Intensive and extensive excavation are recommended for the Peterson and Upper Terrace sites, respectively. Continual monitoring is recommended for all sites in proximity to Hebgen Lake so that future collections can be made to augment current knowledge of the area. Since the historic sites have been identified but not studied, work should be undertaken to assess the significance of each site.

The mitigating tactics presented above can reduce the potentially negative impacts to a significant degree, *if* persistent efforts are made to establish that archaeological or historical remains are neither damaged nor eliminated during the construction program. If remains are threatened unavoidably, steps can be taken in the field to protect, collect and preserve them to prevent their waste. These non-renewable resources do constitute an integral part of the natural environment.

ACKNOWLEDGMENTS

Charles (Denny) Zeier and Robert Peterson did a creditable piece of work in the project area. Their determination and perseverance in overcoming the evident paucity of archaeological materials is a credit to their resourcefulness.

John Montagne was a most cooperative and understanding project leader and coordinator.

Hans Geier, manager of Ski Yellowstone, Inc., was ever helpful. Use of the company cabins made the stay in Red Canyon pleasurable and the work more productive.

Joann Stovall provided her personal artifact collection for examination and permitted obsidian artifacts to be thin sectioned for hydration dating. Her specimens were material in heightening our understanding of prehistoric evidence in the study area.

George Schaller, assistant district ranger from the Hebgen Ranger District, facilitated our survey by obtaining a blanket exploration permit that covered the National Forest lands included in the project area.

Stuart Conner provided valuable memoranda and photographs that made our information coverage more comprehensive.

Wayne Replogle, ranger in Yellowstone National Park, kindly and enthusiastically toured the field crew through sites in the Park. His knowledge of the area is remarkable. The tour was certainly one of the highlights of the summer.

The members of Ski Yellowstone, Inc., should be commended for their foresight in seeking professional counsel in the planning of this recreational development. Their concerns are shared by all of us. It has been a pleasure being of service to the company.

Zeier prepared the maps (Figures 1, 2, and 3) and Peterson handled the photographic tasks, both under my direction.

Mrs. Marlene Short, Department of Sociology, and Mrs. May Mace, Museum of the Rockies, typed preliminary drafts and the final report.

Table 1 Archaeological and Historic Sites Inventory, Hebgen-Red Canyon Creek Project 1973, Part I

Site Name	Site Number	Legal Description	Drainage/ Phys Unit	Type of Site	Site Status
Prehistoric Sites:					
On-Site-					
Y-Bother	24GA698	SE¼ Sec. 26, T11S, R4E	Red Canyon Creek	Habitation	Test excavated
Peterson	24GA699	SE¼ Sec. 2, T12S, R4E	Red Canyon Creek	Habitation	Test excavated
Upper Terrace	24GA1133	SE¼ Sec. 2, T12S, R4E	Red Canyon Creek	Habitation	Test excavated
Main Cabin	24GA1139		Red Canyon Creek	Habitation	Test excavated
Grayling Road	24GA1134	NW¼ Sec. 12, T12S, R4E	Red Canyon Creek	Habitation	Surface collected
Hebgen Mountain	24GA1135	N½ Sec. 3, T12S, R4E	Hebgen Peak	Possible chert quarry	Surface collected
Hill 8625	24GA1136	E½ Sec. 28, T11S, R4E	Hebgen Peak	Possible chert quarry	Surface collected
Corey Springs	24GA326	Sec. 23 T12S, R4E	Corey Springs	Habitation	Surface collected

Table 1 Archaeological and Historic Sites Inventory, Hebgen-Red Canyon Creek Project 1973, Part I (continued)

Site Name	Site Number	Legal Description	Drainage/ Phys Unit	Type of Site	Site Status
Prehistoric Sites:					
Off-Site-					
Dandelion Meadow	24GA696	NE¼ Sec. 6, T11S, R5E	Graycroft Ridge	Habitation	Surface collected
Bumblebee Meadow	24GA697	NE¼ Sec. 6, T11S, R5E	Graycroft Ridge	Habitation	Surface collected
Lake Shore	24GA700	SW¼ Sec. 3, T12S, R4E	Hebgen Lake	Habitation	Surface collected
Narrows Spit	24GA1131	Secs. 10, 11, 14, 15, T12S, R4E	Hebgen Lake	Habitation	Surface collected
Rainbow Point	24GA1132	Secs. 13, 23, 24, T12S, R4E	Hebgen Lake	Habitation	Surface collected
Historic Sites:					
Old Cabin	24GA695	NW¼ Sec. 2, T12S, R4E	Red Canyon Creek	Habitation	Identified but not collected
Old Cabin II	24GA1137		Red Canyon Creek	Habitation	Identified but not collected

Table 1 Archaeological and Historic Sites Inventory, Hebgen-Red Canyon Creek Project 1973, Part I (continued)

Site Name	Site Number	Legal Description	Drainage/ Phys Unit	Type of Site	Site Status
Barn	24GA1138		Red Canyon Creek	Habitation	Identified but not collected
Grayling Townsite	See text by John De Haas appended.				

Table 2 Archaeological and Historic Sites Inventory, Hebgen-Red Canyon Creek Project 1973, Part II

Site Name	Volume Excavated	Collections Made	Photographic Record	Further Work Recommended
Prehistoric Sites:				
On-Site-				
Y-Bother	2.25m^3	Surface and sub-surface	35 mm B&W/ Kodacolor	None
Peterson	5.25 m^3	Surface and sub-surface	35 mm B&W/ Kodacolor	Intensive excavation
Upper Terrace	3.33 m^3	Sub-surface	35 mm Kodacolor	Extensive excavation
Main Cabin	2.00 m^3	Surface and sub-surface	35 mm B&W/ Kodacolor	None
Grayling Road	None	Surface	35 mm B&W/ Kodacolor	None
Hebgen Mountain	None	Surface	35 mm Kodacolor	None
Hill 8625	None	Surface	35 mm Kodacolor	None
Corey Springs	None	Surface	35 mm Kodacolor	Continual monitoring and periodic low water excavation of exposed features

Table 2 Archaeological and Historic Sites Inventory, Hebgen-Red Canyon Creek Project 1973, Part II (continued)

Site Name	Volume Excavated	Collections Made	Photographic Record	Further Work Recommended
Prehistoric Sites:				
Off-Site-				
Dandelion Meadow	None	Surface	35 mm B&W/ Kodacolor	More extensive surface reconnaissance
Bumblebee Meadow	None	Surface	35 mm B&W/ Kodacolor	More extensive surface reconnaissance
Lake Shore	None	Surface	Kodacolor	Periodic monitoring
Narrows Spit	None	Surface	Kodacolor	Periodic monitoring
Rainbow Point	None	Surface and private coll. recorded	35 mm B&W/ Kodacolor	Periodic monitoring at low water
Historic Sites:				
Old Cabin	None	None	35 mm B&W/ Kodacolor	Record architectural features and collect movable historic artifacts
Old Cabin II	None	None	None	Same as above

Table 2 Archaeological and Historic Sites Inventory, Hebgen-Red Canyon Creek Project 1973, Part II (continued)

Site Name	Volume Excavated	Collections Made	Photographic Record	Further Work Recommended
Barn	None	None	None	Record architectural features and collect movable historic artifacts
Grayling Townsite	Refer to text by John DeHaas.			

Table 3 Archaeological and Historic Sites Inventory, Hebgen-Red Canyon Creek Project 1973, Part III

Site Name	Features Identified	Artifacts Observed	Lithic Types	Faunal Remains	Cultural Phases	Cultural Periods
Prehistoric Sites:						
On-Site-						
Y-Bother	None	Edge retouched	Obsidian, basalt, quartzite, chert, chalcedony, jasper	Bone splinters	Unknown	Unknown
Peterson	Buried hearth	Bone awl	Obsidian, chert, chalcedony	Bison	Unknown	Unknown
Upper Terrace	None	None	Obsidian, quartzite, chert	Bison	Unknown	Unknown
Main Cabin	None	None	None	Bison, deer, other	Unknown	Unknown
Grayling Road	None	Knife	Chert, jasper	None	Unknown	Unknown
Hebgen Mountain	None	None	Chert in ledge	None	Unknown	Unknown

Table 3 Archaeological and Historic Sites Inventory, Hebgen-Red Canyon Creek Project 1973, Part III (continued)

Site Name	Features Identified	Artifacts Observed	Lithic Types	Faunal Remains	Cultural Phases	Cultural Periods
Hill 8625	None	None	Chert in ledge	None	Unknown	Unknown
Corey Springs	Rock mounded hearths	Projectile points, scrapers, knives, drills, edge re-touched flakes, cores	Obsidian, basalt, quartzite, chert, chalcedony, jasper, agate, opalized wood	Bison, deer, elk, coyote, other	Hanna, Pelican Lake, Old Women's	Middle, Late
Off-Site-						
Dandelion Meadow	None	None	Obsidian, chert	None	Unknown	Unknown
Bumblebee Meadow	None	None	None	Bison	Unknown	Unknown
Lake Shore	None	Edge retouched flakes	Obsidian, basalt, quartzite, chert, chalcedony, jasper	None	Unknown	Unknown

Table 3 Archaeological and Historic Sites Inventory, Hebgen-Red Canyon Creek Project 1973, Part III (continued)

Site Name	Features Identified	Artifacts Observed	Lithic Types	Faunal Remains	Cultural Phases	Cultural Periods
Narrows Spit	None	Edge retouched flakes, projectile point	Obsidian, chert, chalcedony	None	Unknown	Unknown
Rainbow Point	None	Every type known in region	Every type known in region	Not recorded	McKean, Hanna, Pelican Lake, Old Women's	Early, Middle, Late

Historic Sites:

This characterization not relevant to historic sites.

Table 4 Frequency Distribution of Lithic Varieties Across Prehistoric Sites in the Hebgen-Red Canyon Creek Locality

Site	Obsidian		Ignimbrite	Basalt	Opalized Wood	Chalcedony					Chert							Jasper			Quartzite			Mudstone	Slate	Totals
	O	T				W	Y	R	G	Br	B	W	Y	R	G	T	Br	Y	R	Br	W	Y	G			
Y-Bother																										
Surface	10	5	2	1								1		1	2								1		2	25
Test C														1		1										2
Test D												1														1
Test F	4	9		1							5	7	2	4	7					1						40
Test G	2	2		2						1	2	3			9		1			1						23
Test H	4	3									1				7											15
Peterson																										
Surface	7							1				1			1											10
Test A																										0
Test B	1														2											3
Upper Terrace																										
Test A	15	1	2			2						8	2					1	1		2					34

Table 4 Frequency Distribution of Lithic Varieties Across Prehistoric Sites in the Hebgen-Red Canyon Creek Locality (Continued)

Site	Obsidian		Ignimbrite	Basalt	Opalized Wood	Chalcedony					Chert							Jasper			Quartzite			Mudstone	Slate	Totals
	O	T				W	Y	R	G	Br	B	W	Y	R	G	T	Br	Y	R	Br	W	Y	G			
Main Cabin																										
Test A																										0
Test B																										0
Grayling Road																										
Surface														1	1					1						3
Hebgen Mountain																										
Surface 1																										1
Hill 8625																										
Surface																										0
Corey Springs																										
Surface	39	39	48	3	1		1	1		2	1	6	9	3	4		14				1	1	1			175

Table 4 Frequency Distribution of Lithic Varieties Across Prehistoric Sites in the Hebgen-Red Canyon Creek Locality (Continued)

Site	Obsidian		Ignimbrite	Basalt	Opalized Wood	Chalcedony					Chert							Jasper			Quartzite			Mudstone	Slate	Totals
	O	T				W	Y	R	G	Br	B	W	Y	R	G	T	Br	Y	R	Br	W	Y	G			
Dandelion Meadow																										
Surface	2																1									3
Bumblebee Meadow																										
Surface																										0
Lake Shore																										
Surface	4	3	6	3			1		1					2						1				1		22
Narrows Spit																										
Surface	2	4	28									1				7				4						48
Rainbow Point																										
Surface	No collection attempted; under water																									
Total:																										405

Table 5 Absolute Ages of Archaeological Obsidian Samples Recovered from Sites in the Hebgen-Red Canyon Creek Project Area 1973

Specimen	NW Plains Project No.	Hydration Lab No.	Hydration (in microns)	Hydration (in microns^2)	Hydration Age (years B.P.)	Hydration Age (years B.C./A.D.)
Y-Bother (24GA698)						
Flake	D2425	M780	.98	.96	217	A.D. 1756
Flake	D2379	M733	1.83	3.35	756	A.D. 1217
Flake	D2377	M731	1.87	3.50	790	A.D. 1183
Flake	D2373	M727	2.16	4.67	1054	A.D. 919
Flake	D2389	M743	2.38	5.66	1278	A.D. 695
Flake	D2386	M740	2.49	6.20	1400	A.D. 573
Flake	D2382	M736	2.58	6.66	1503	A.D. 470
Flake	D2390	M744	2.65	7.02	1585	A.D. 388
Flake	D2388	M742	2.68	7.18	1621	A.D. 352
Flake	D2371	M725	2.70	7.29	1646	A.D. 327
Flake	D2431	M786	2.73	7.45	1682	A.D. 291
Flake	D2426	M781	2.85	8.12	1833	A.D. 140
Flake	D2376	M730	2.85	8.12	1833	A.D. 140
Flake	D2384	M738	2.85	8.12	1833	A.D. 140
Flake	D2385	M739	2.94	8.64	1950	A.D. 23
Flake	D2432	M787	3.14	9.86	2226	253 B.C.
Flake	D2383	M737	3.24	10.50	2370	397 B.C.
Flake	D2374	M728	3.46	11.97	2702	729 B.C.
Flake	D2387	M741	3.55	12.60	2844	871 B.C.
Flake	D2375	M729	3.61	13.03	2941	968 B.C.
Flake	D2378	M732	3.64	13.25	2991	1018 B.C.
Flake	D2380	M734	4.62	21.34	4817	2844 B.C.
Flake	D2372	M726	6.71	45.02	10162	8189 B.C.

Table 5 Absolute Ages of Archaeological Obsidian Samples Recovered from Sites in the Hebgen-Red Canyon Creek Project Area 1973 (continued)

Specimen	NW Plains Project No.	Hydration Lab No.	Hydration (in microns)	Hydration (in $microns^2$)	Hydration Age (years B.P.)	Hydration Age (years B.C./A.D.)
Peterson (24GA699)						
Flake	D2392	M746	2.13	4.54	1025	A.D. 948
Flake	D2395	M749	2.42	5.86	1323	A.D. 650
Flake	D2391	M745	2.49	6.20	1400	A.D. 573
Flake	D2396	M750	2.50	6.25	1411	A.D. 562
Flake	D2394	M748	2.95	8.70	1964	A.D. 9
Flake	D2393	M747	3.02	9.12	2059	86 B.C.
Upper Terrace (24GA1133)						
Flake	D2427	M782	2.54	6.45	1456	A.D. 517
Flake	D2428	M783	2.57	6.60	1490	A.D. 483
Flake	D2430	M785	3.05	9.30	2099	126 B.C.
Flake	D2429	M784	3.08	9.49	2142	169 B.C.
Hebgen Mountain (24GA1135)						
Flake	D2359	M713	2.95	8.70	1964	A.D. 9
Corey Springs (24GA326)						
Flake	D2320	M751	Too small to measure.			
Flake	D2347	M701	2.13	4.54	1025	A.D. 948
Flake	D2322	M676	2.37	5.62	1269	A.D. 704
Flake	D2345	M699	2.44	5.95	1343	A.D. 630
Flake	D2332	M686	2.47	6.10	1377	A.D. 596
Flake	D2353	M707	2.49	6.20	1400	A.D. 573

Table 5 Absolute Ages of Archaeological Obsidian Samples Recovered from Sites in the Hebgen-Red Canyon Creek Project Area 1973 (continued)

Specimen	NW Plains Project No.	Hydration Lab No.	Hydration (in microns)	Hydration (in microns^2)	Hydration Age (years B.P.)	Hydration Age (years B.C./A.D.)
Flake	D2326	M680	2.58	6.66	1503	A.D. 470
Flake	D2341	M695	2.63	6.92	1562	A.D. 411
Flake	D2357	M711	2.76	7.62	1720	A.D. 253
Flake	D2335	M689	2.86	8.18	1847	A.D. 126
Flake	D2337	M691	2.86	8.18	1847	A.D. 126
Flake	D2355	M709	2.92	8.53	1926	A.D. 47
Flake	D2341	M695	2.92	8.53	1926	A.D. 47
Flake	D2327	M681	2.92	8.53	1926	A.D. 47
Flake	D2330	M684	2.94	8.64	1950	A.D. 23
Flake	D2358	M712	2.98	8.88	2005	32 B.C.
Flake	D2349	M703	3.05	9.30	2099	126 B.C.
Flake	D2351	M705	3.06	9.36	2113	140 B.C.
Flake	D2354	M708	3.12	9.73	2196	223 B.C.
Flake	D2338	M692	3.18	10.11	2282	309 B.C.
Flake	D2343	M697	3.61	13.03	2941	968 B.C.
Flake	D2339	M693	3.78	14.29	3226	1253 B.C.
Flake	D2323	M677	3.80	14.44	3260	1287 B.C.
Flake	D2350	M704	3.81	14.52	3278	1305 B.C.
Flake	D2328	M682	3.82	14.59	3293	1320 B.C.
Flake	D2356	M710	4.25	18.06	4077	2104 B.C.
Flake	D2352	M706	4.30	18.49	4174	2201 B.C.
Flake	D2340	M694	4.64	21.53	4860	2887 B.C.
Flake	D2321	M675	4.67	21.81	4923	2950 B.C.
Flake	D2336	M690	5.16	26.63	6011	4038 B.C.
Flake	D2325	M679	5.18	26.83	6056	4083 B.C.
Flake	D2329	M683	5.25	27.56	6221	4248 B.C.
Flake	D2334	M688	5.40	29.16	6582	4609 B.C.
Flake	D2331	M685	5.49	30.14	6804	4831 B.C.
Flake	D2344	M698	5.60	31.36	7079	5106 B.C.

Table 5 Absolute Ages of Archaeological Obsidian Samples Recovered from Sites in the Hebgen-Red Canyon Creek Project Area 1973 (continued)

Specimen	NW Plains Project No.	Hydration Lab No.	Hydration (in microns)	Hydration (in microns^2)	Hydration Age (years B.P.)	Hydration Age (years B.C./A.D.)
Flake	D2346	M700	5.77	33.29	7515	5542 B.C.
Flake	D2333	M687	5.78	33.41	7542	5569 B.C.
Flake	D2348	M702	6.06	36.72	8288	6315 B.C.
Flake	D2324	M678	7.18	51.55	11637	9664 B.C.
Dandelion Meadow (24GA696)						
Flake	D2382	M735	3.17	10.05	2269	296 B.C.
Lake Shore (24GA700)						
Flake	D2367	M721	1.10	1.21	273	A.D. 1700
Flake	D2365	M719	2.75	7.56	1707	A.D. 266
Flake	D2370	M724	2.80	7.84	1770	A.D. 203
Flake	D2369	M723	3.06	9.36	2113	140 B.C.
Flake	D2366	M720	3.24	10.50	2370	397 B.C.
Flake	D2368	M722	4.55	20.70	4673	2700 B.C.
Narrows Spit (24GA1131)						
Flake	D2364	M718	No visible hydration.			
Flake	D2361	M715	4.16	17.31	3907	1934 B.C.
Flake	D2362	M716	4.63	21.44	4840	2867 B.C.
Flake	D2360	M714	4.66	21.72	4903	2930 B.C.
Flake	D2363	M717	5.68	32.26	7282	5309 B.C.

Table 5 Absolute Ages of Archaeological Obsidian Samples Recovered from Sites in the Hebgen-Red Canyon Creek Project Area 1973 (continued)

Specimen	NW Plains Project No.	Hydration Lab No.	Hydration (in microns)	Hydration (in $microns^2$)	Hydration Age (years B.P.)	Hydration Age (years B.C./A.D.)
Rainbow Point (24GA1132)						
Point	D2402	M757	No visible hydration.			
Point	D2528	M807	1.93	3.72	840	A.D. 1133
Point	D2403	M758	2.08	4.33	977	A.D. 996
Point	D2416	M771	2.59	6.71	1515	A.D. 458
Point	D2407	M762	2.84	8.07	1822	A.D. 151
Point	D2422	M777	3.23	10.43	2354	381 B.C.
Point	D2524	M803	3.31	10.96	2474	501 B.C.
Knife	D2521	M800	3.55	12.60	2884	911 B.C.
Point	D2408	M763	3.73	13.91	3140	1167 B.C.
Point	D2529	M808	3.81	14.52	3278	1305 B.C.
Uniface	D2413	M768	3.92	15.37	3470	1497 B.C.
Uniface	D2410	M765	4.06	16.48	3720	1747 B.C.
Point	D2523	M802	4.15	17.22	3887	1914 B.C.
Scraper	D2525	M804	4.20	17.64	3982	2009 B.C.
Uniface	D2412	M767	4.23	17.89	4038	2065 B.C.
Scraper	D2421	M779	4.26	18.15	4097	2124 B.C.
Point	D2399	M754	4.29	18.40	4153	2180 B.C.
Point(?)	D2527	M806	4.31	18.58	4194	2221 B.C.
Point	D2418	M773	4.32	18.66	4212	2239 B.C.
Point	D2417	M772	4.32	18.66	4212	2239 B.C.
Point	D2397	M752	4.40	19.36	4370	2397 B.C.
Core	D2411	M766	4.46	19.89	4490	2517 B.C.
Uniface	D2409	M764	4.50	20.25	4571	2598 B.C.
Point	D2415	M770	4.59	21.07	4756	2783 B.C.
Point	D2526	M805	4.59	21.07	4756	2783 B.C.
Point	D2420	M775	4.62	21.34	4817	2844 B.C.
Point	D2421	M776	4.75	22.56	5093	3120 B.C.
Point	D2401	M756	4.79	22.94	5178	3205 B.C.

Table 5 Absolute Ages of Archaeological Obsidian Samples Recovered from Sites in the Hebgen-Red Canyon Creek Project Area 1973 (continued)

Specimen	NW Plains Project No.	Hydration Lab No.	Hydration (in microns)	Hydration (in microns^2)	Hydration Age (years B.P.)	Hydration Age (years B.C./A.D.)
Point	D2423	M778	5.07	25.70	5801	3828 B.C.
Point	D2419	M774	5.25	27.56	6221	4248 B.C.
Point	D2414	M769	5.25	27.56	6221	4248 B.C.
Point	D2404	M759	5.28	27.88	6293	4320 B.C.
Point	D2398	M753	5.60	31.36	7079	5106 B.C.
Point	D2406	M761	5.68	32.26	7282	5309 B.C.
Point	D2522	M801	5.69	32.38	7309	5336 B.C.
Point	D2400	M755	6.00	36.00	8126	6153 B.C.
Point	D2405	M760	6.84	46.79	10562	8589 B.C.

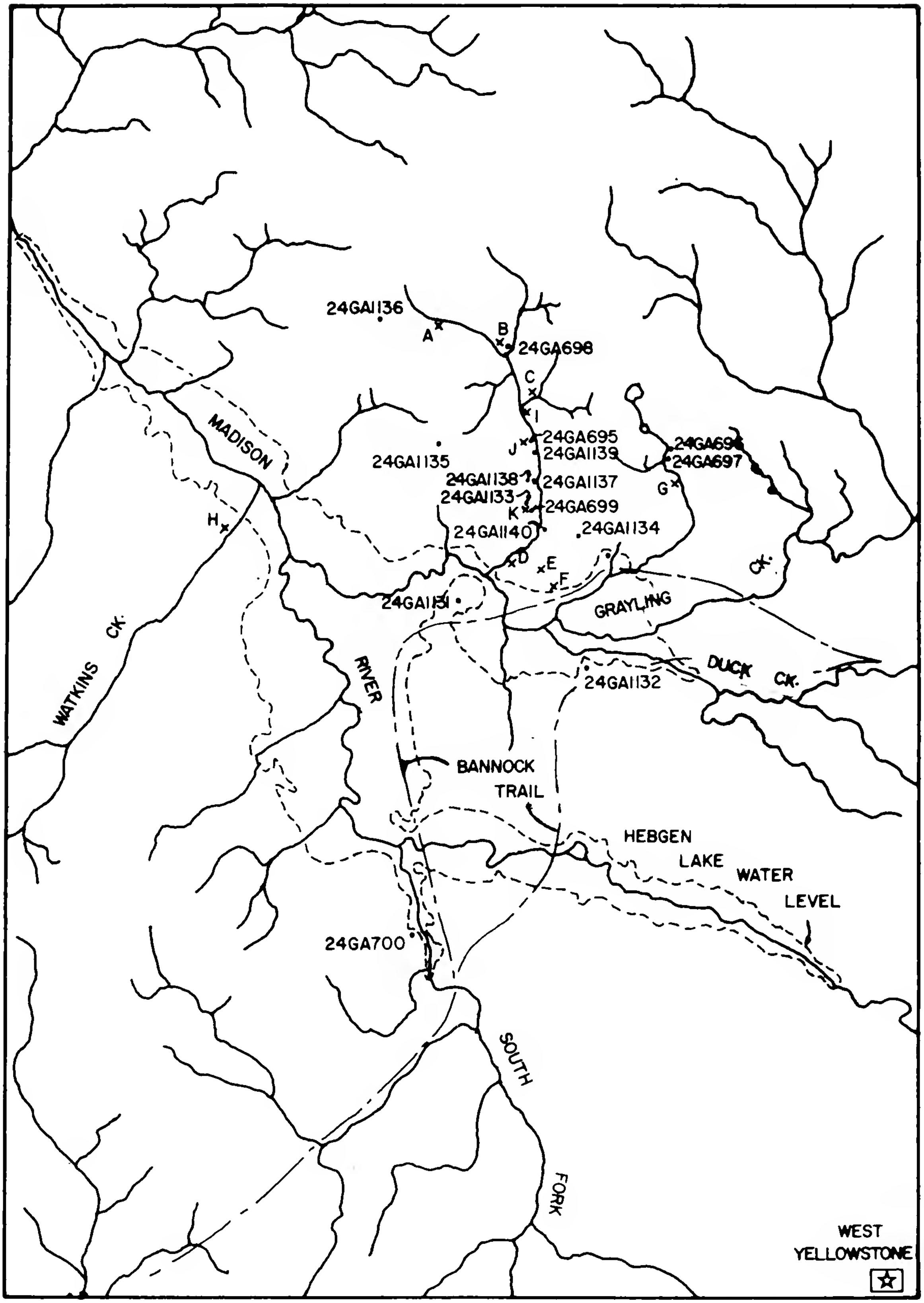

Fig. 1. Site and Find Spot Distribution in the Project Area.

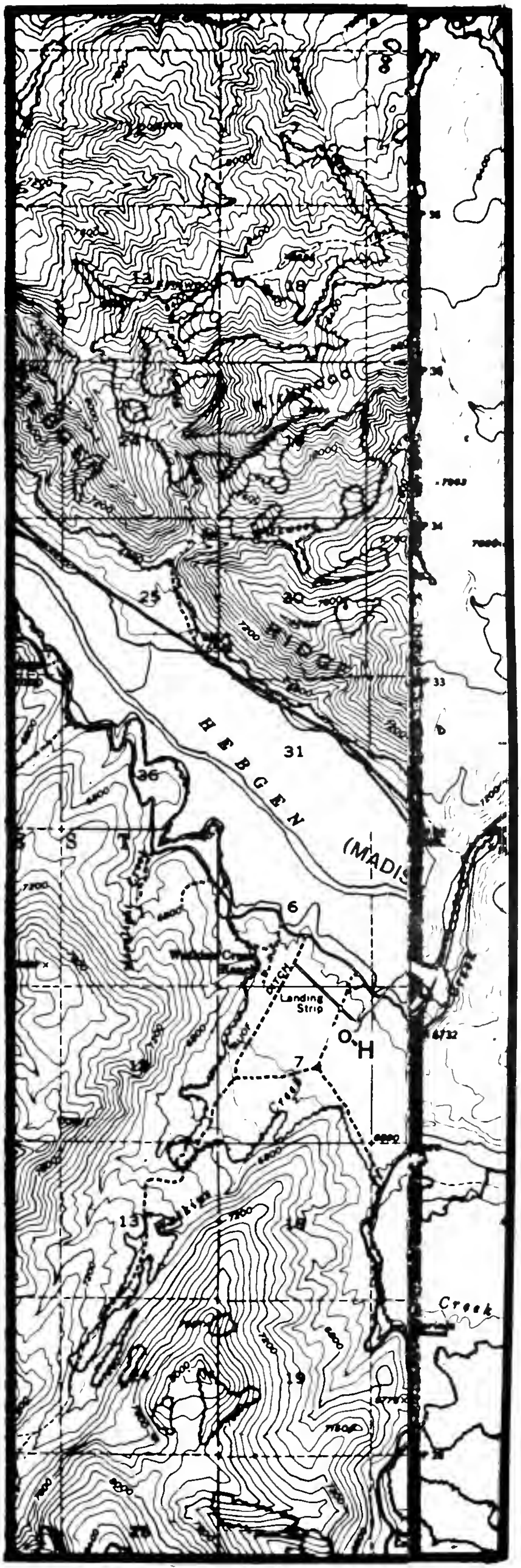

FIGURE 2

ENVIRONMENTAL SUMMARY
SECONDARY STUDY AREA

ARCHAEOLOGY
INVENTORY

BY: LESLIE B. DAVIS

ARCHAEOLOGICAL SITES

* HISTORICAL SITES

O FIND AREAS

BANNOCK TRAIL

SKI YELLOWSTONE

SKI YELLOWSTONE INC.
WEST YELLOWSTONE, MONTANA

SCALE 1: 62500

0 5000 10,000 FEET

0 1 2 MILES

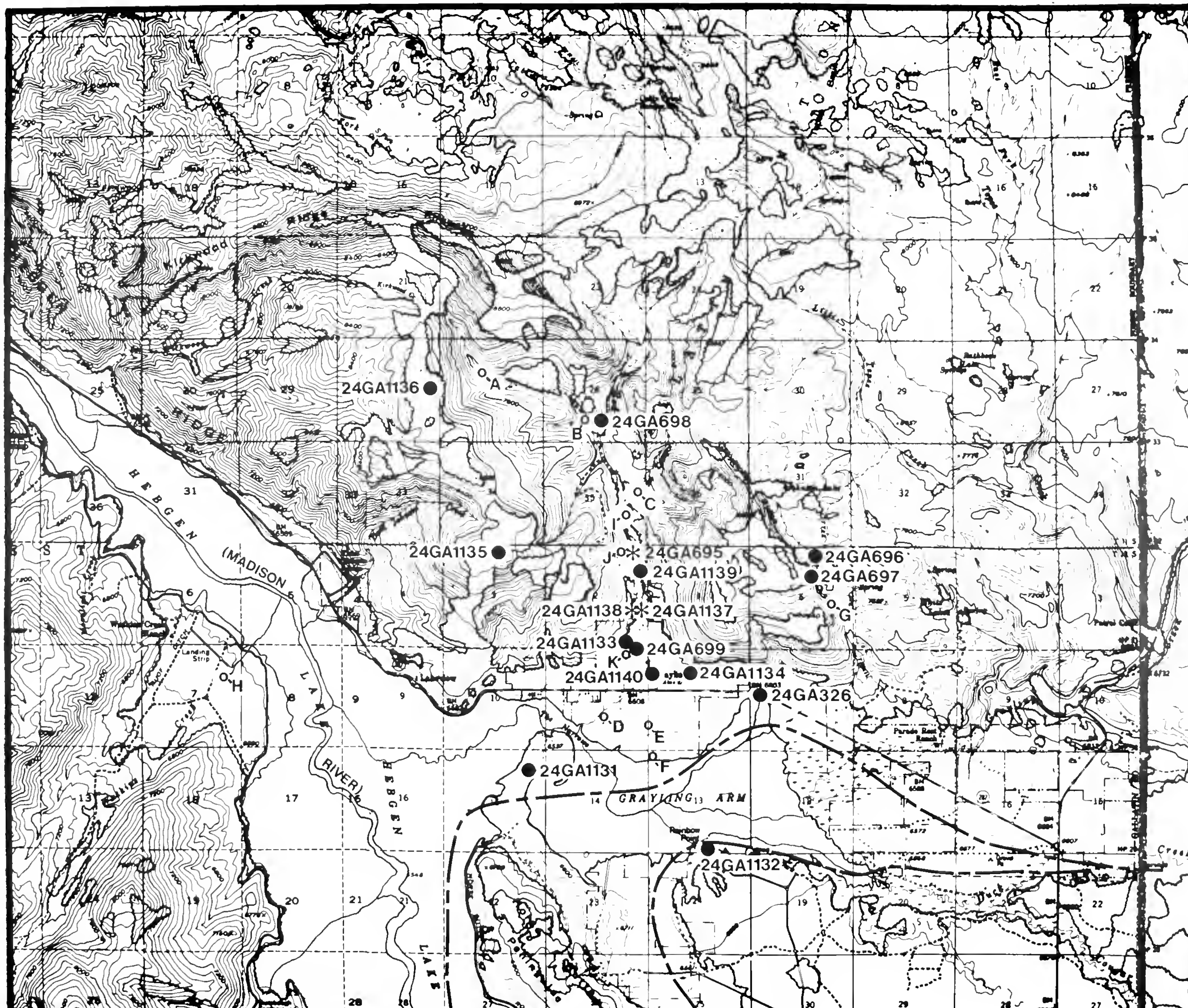

FIGURE 2

ENVIRONMENTAL SUMMARY
SECONDARY STUDY AREA

ARCHAEOLOGY INVENTORY

BY: LESLIE B. DAVIS

● ARCHAEOLOGICAL SITES

✳ HISTORICAL SITES

o FIND AREAS

BANNOCK TRAIL

SKI YELLOWSTONE

SKI YELLOWSTONE INC.
WEST YELLOWSTONE, MONTANA

SCALE 1:62500

0 5000 10,000 FEET

0 1 2 MILES

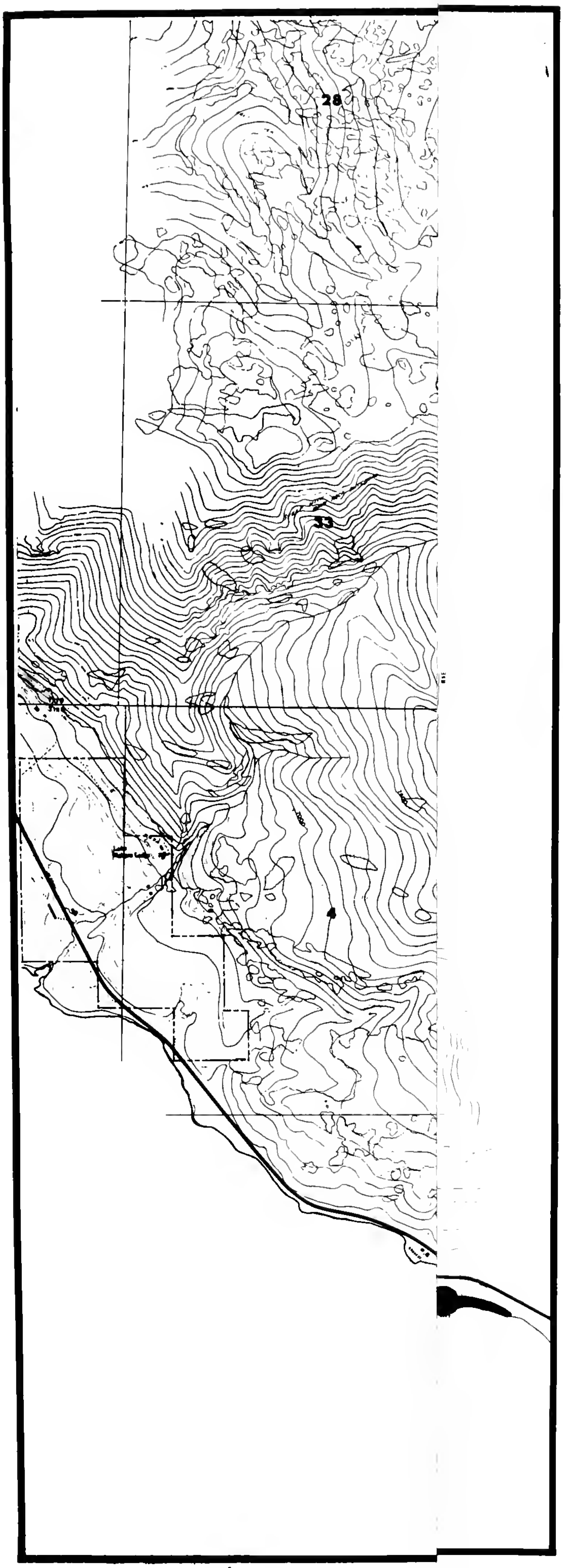

FIGURE 3

ENVIRONMENTAL SUMMARY

PRIMARY STUDY AREA

ARCHAEOLOGY
DEVELOPMENT SENSITIVITY ZONES

BY LESLIE B. DAVIS

FIND SPOTS AND DESIGNATED SITES
(SEE TEXT)

- HIGH SIGNIFICANCE
- 2 MEDIUM SIGNIFICANCE
- 3 LOW SIGNIFICANCE
- 4 LEAST SIGNIFICANCE

DEGREE OF SENSITIVITY

- POTENTIAL HIGH IMPACT
- POTENTIAL MODERATE IMPACT
- POTENTIAL LOW IMPACT

SKI YELLOWSTONE

SKI YELLOWSTONE INC.

WEST YELLOWSTONE, MONTANA

SCALE 1" 2000'

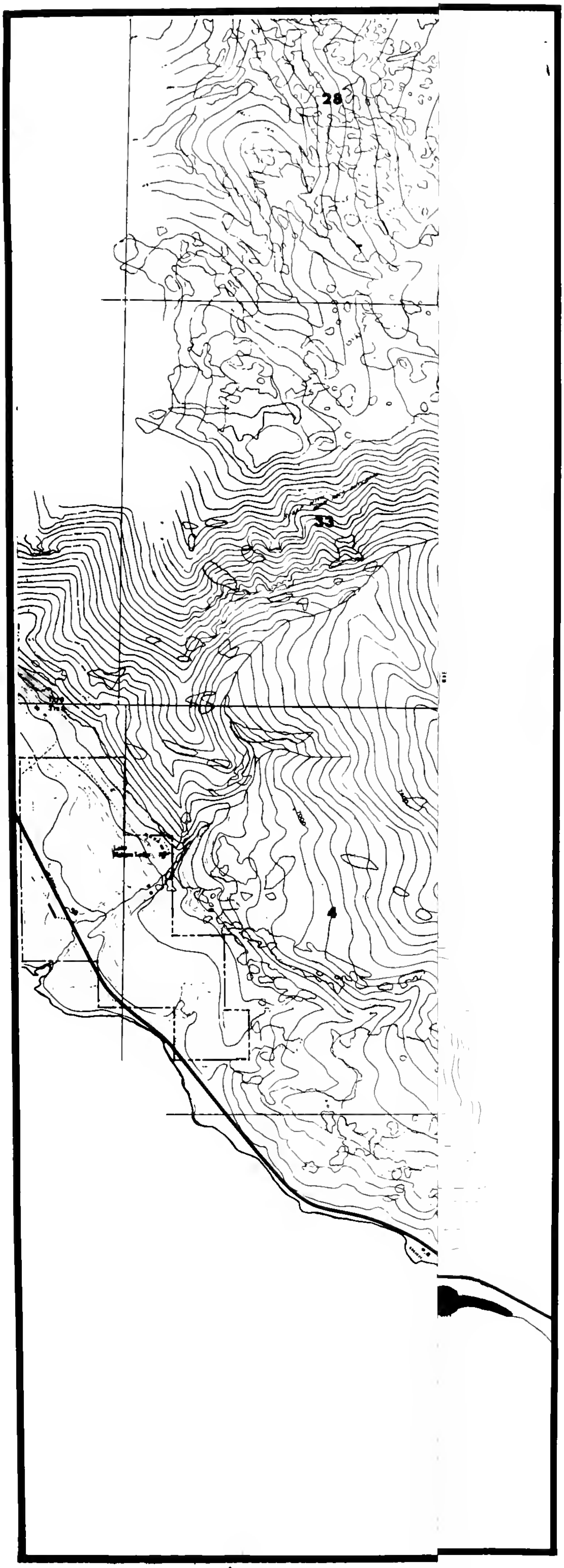

FIGURE 3

ENVIRONMENTAL SUMMARY

PRIMARY STUDY AREA

ARCHAEOLOGY
DEVELOPMENT SENSITIVITY ZONES

BY LESLIE B. DAVIS

FIND SPOTS AND DESIGNATED SITES
(SEE TEXT)

- HIGH SIGNIFICANCE
- 2 MEDIUM SIGNIFICANCE
- 3 LOW SIGNIFICANCE
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DEGREE OF SENSITIVITY

- POTENTIAL HIGH IMPACT
- POTENTIAL MODERATE IMPACT
- POTENTIAL LOW IMPACT

SKI YELLOWSTONE

SKI YELLOWSTONE INC.

WEST YELLOWSTONE, MONTANA

SCALE 1 2000'

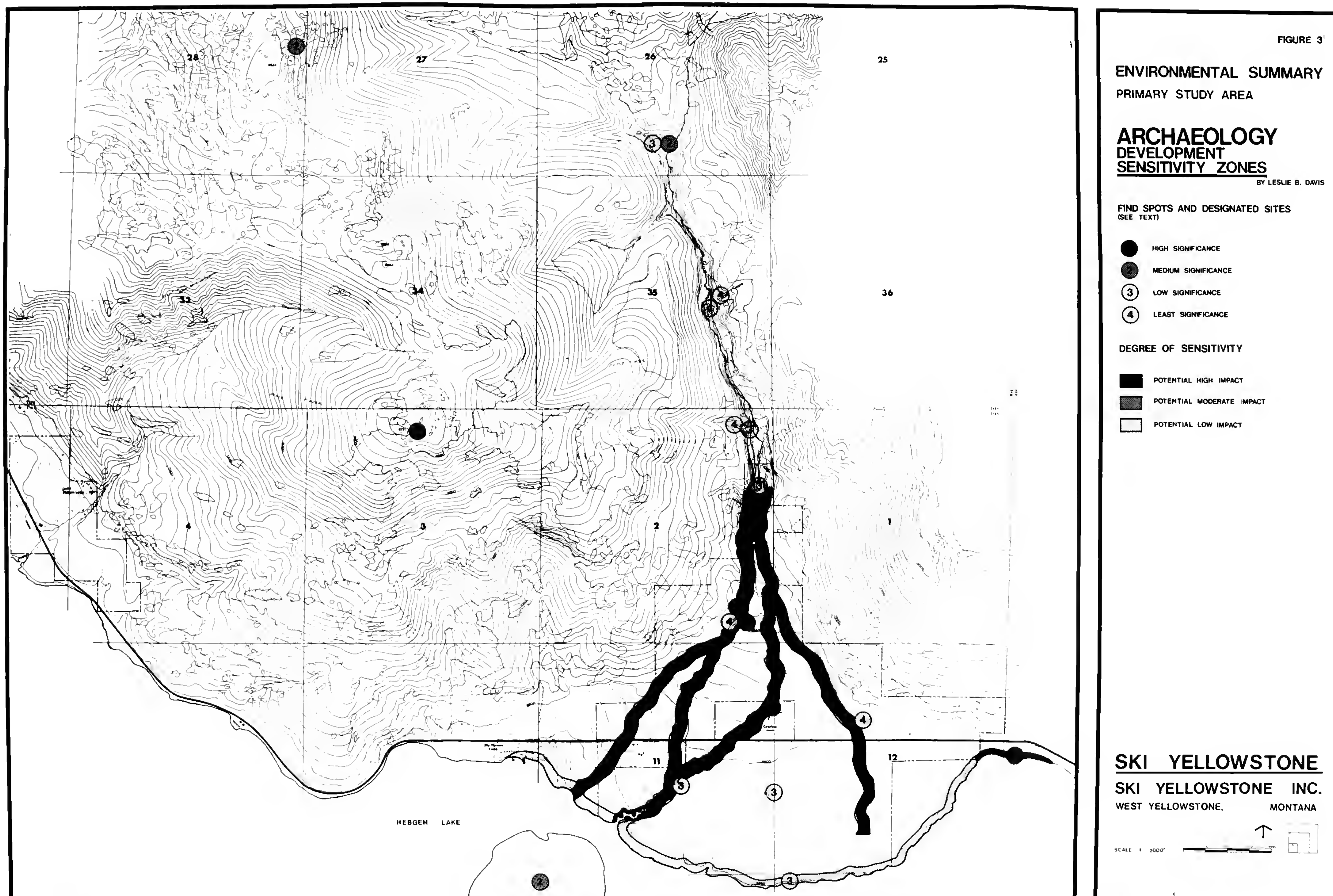
FIGURE 3
ENVIRONMENTAL SUMMARY
PRIMARY STUDY AREA
ARCHAEOLOGY
DEVELOPMENT
SENSITIVITY ZONES
BY LESLIE B. DAVIS
FIND SPOTS AND DESIGNATED SITES
(SEE TEXT)
HIGH SIGNIFICANCE
MEDIUM SIGNIFICANCE
LOW SIGNIFICANCE
LEAST SIGNIFICANCE
DEGREE OF SENSITIVITY
POTENTIAL HIGH IMPACT
POTENTIAL MODERATE IMPACT
POTENTIAL LOW IMPACT
SKI YELLOWSTONE
SKI YELLOWSTONE INC.
WEST YELLOWSTONE, MONTANA
SCALE 1 2000'
HEBGEN LAKE
28
27
26
25
33
34
35
36
4
3
2
1
11
12

Fig. 4. Extensive Colluvial-Alluvial Terrace at the Y-Bother Site, Head of Red Canyon.

Fig. 5. The Hearth at the Peterson Site, Test A.

Fig. 4. Extensive Colluvial-Alluvial Terrace at the Y-Bother Site, Head of Red Canyon.

Fig. 5. The Hearth at the Peterson Site, Test A.

Fig. 6. Excavations at the Upper Terrace Site, Looking East across Red Canyon Fan.

Fig. 7. The Stream-Cut Terrace at the Main Cabin Site on the Left, Looking up Red Canyon Creek.

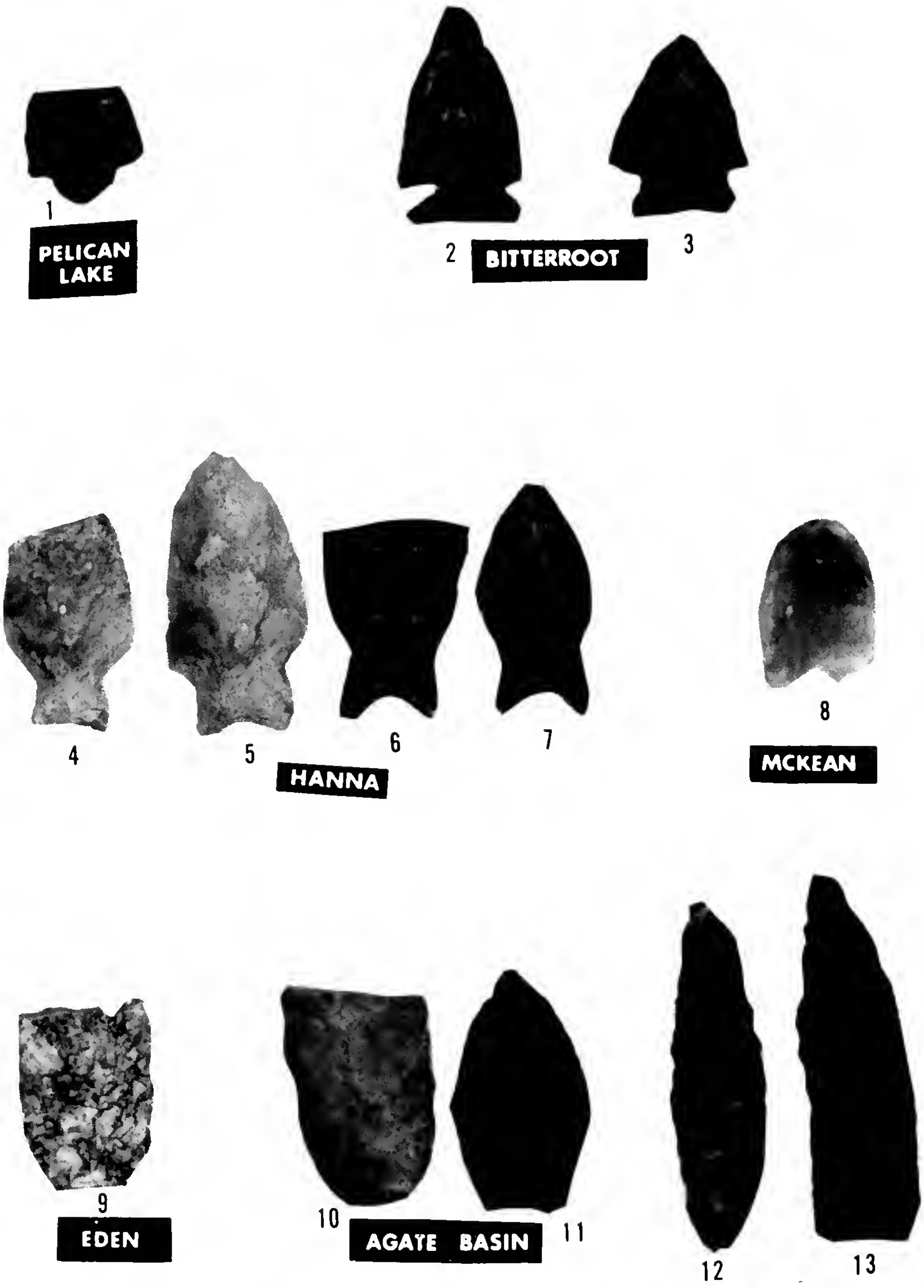

Fig. 8. Artifacts from the Rainbow Point (Stovall) Collection, Projectile Points.

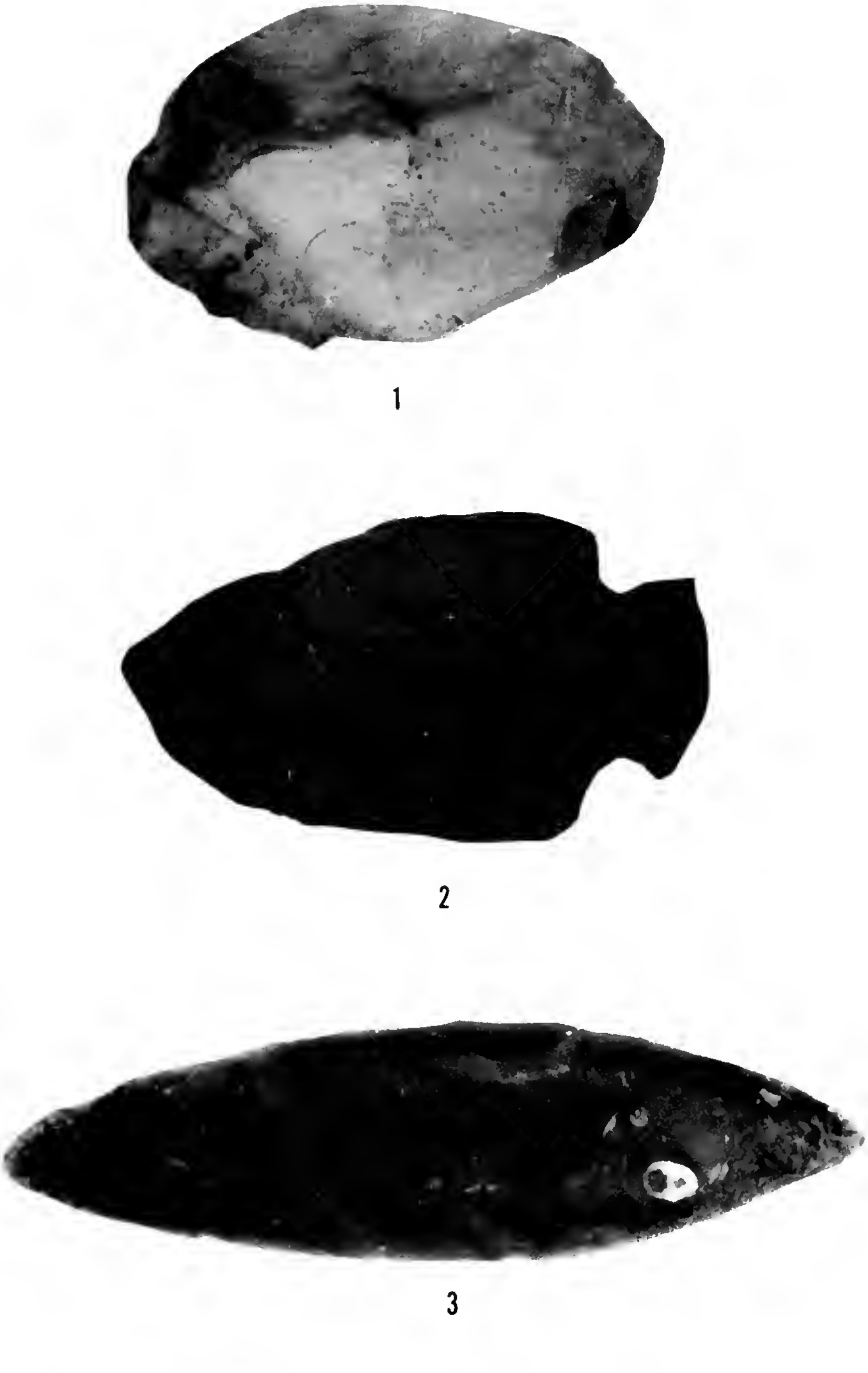

Fig. 9. Artifacts from the Rainbow Point (Stovall) Collection, Knives I.

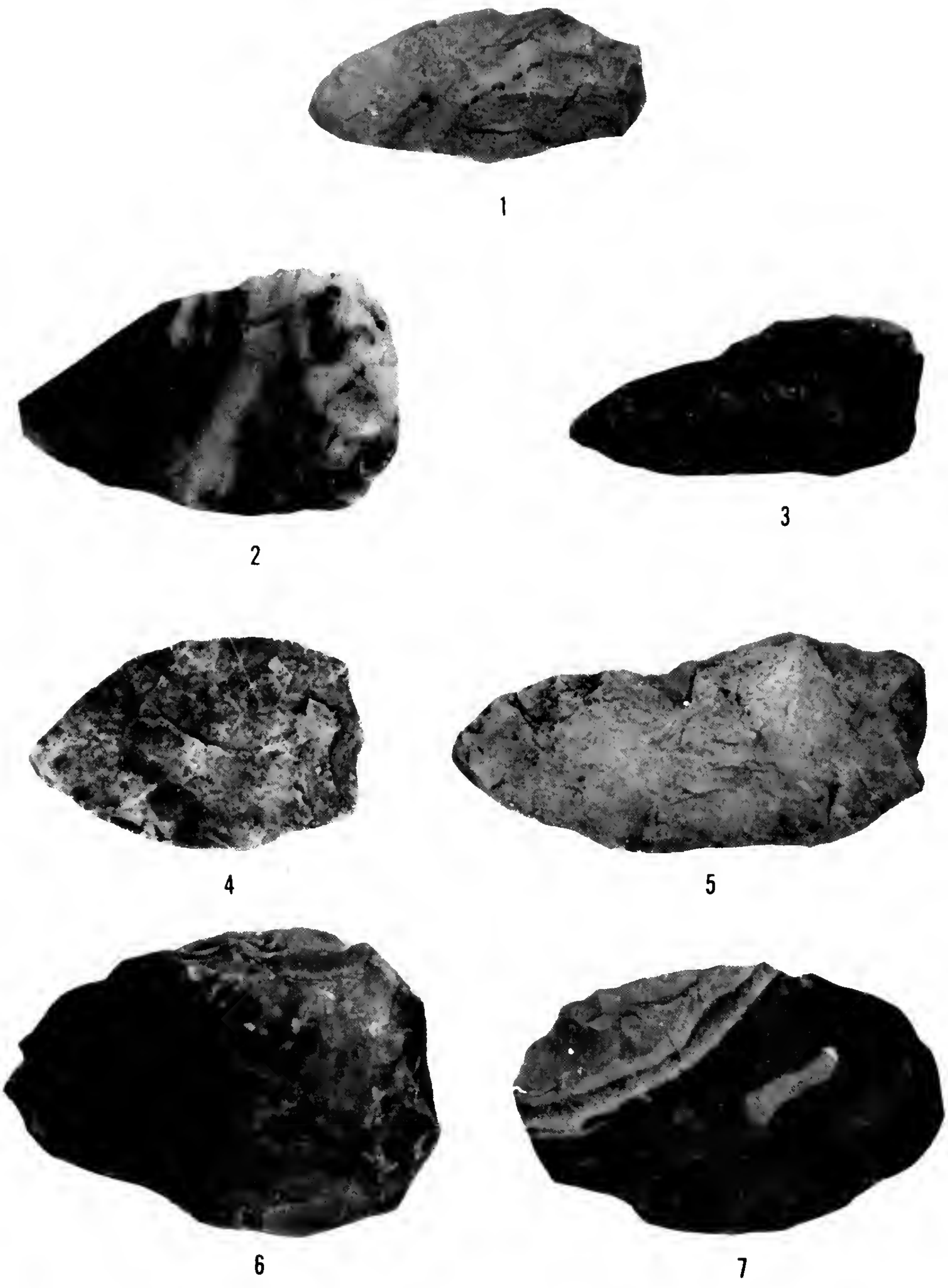

Fig. 10. Artifacts from the Rainbow Point (Stovall) Collection, Knives II.

Fig. 11. Artifacts from the Rainbow Point (Stovall) Collection, End Scrapers.

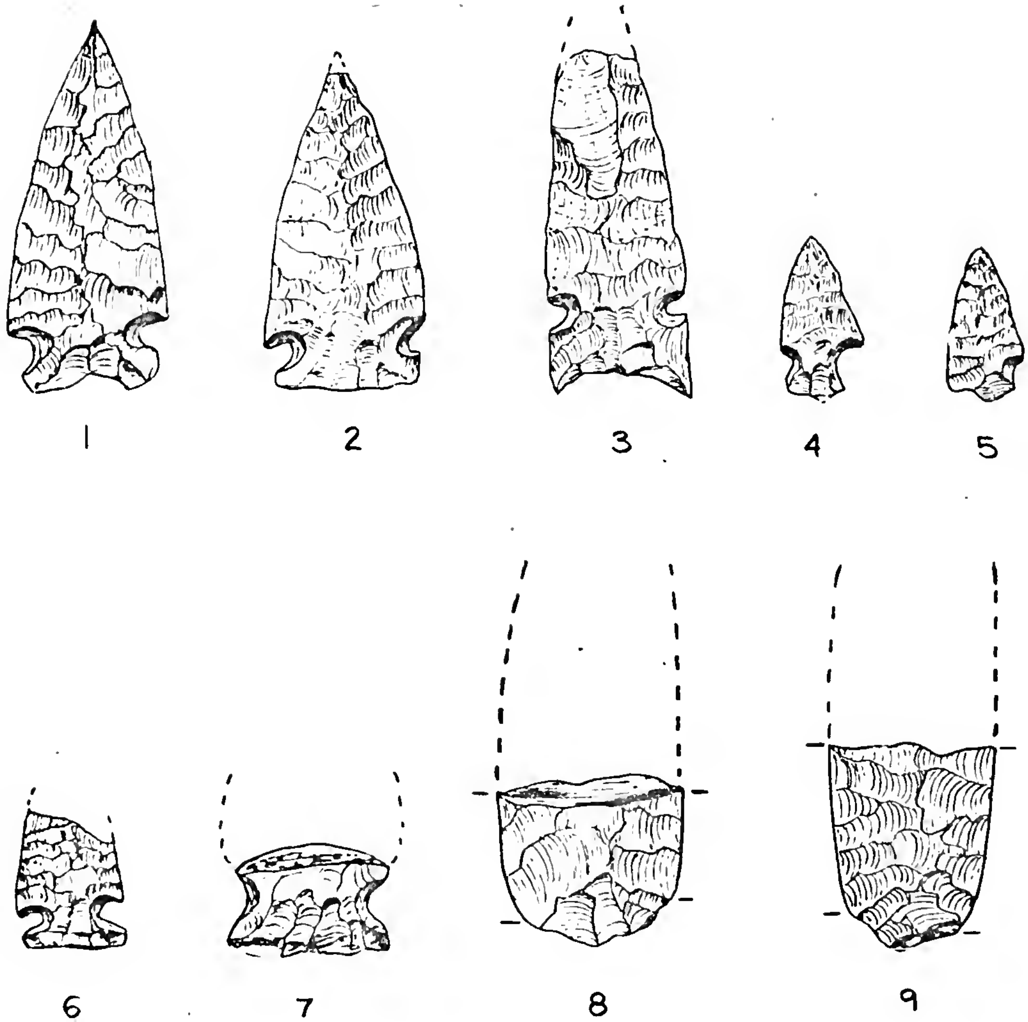

Fig. 12. Artifacts from the Corey Springs (Napton) Collection.

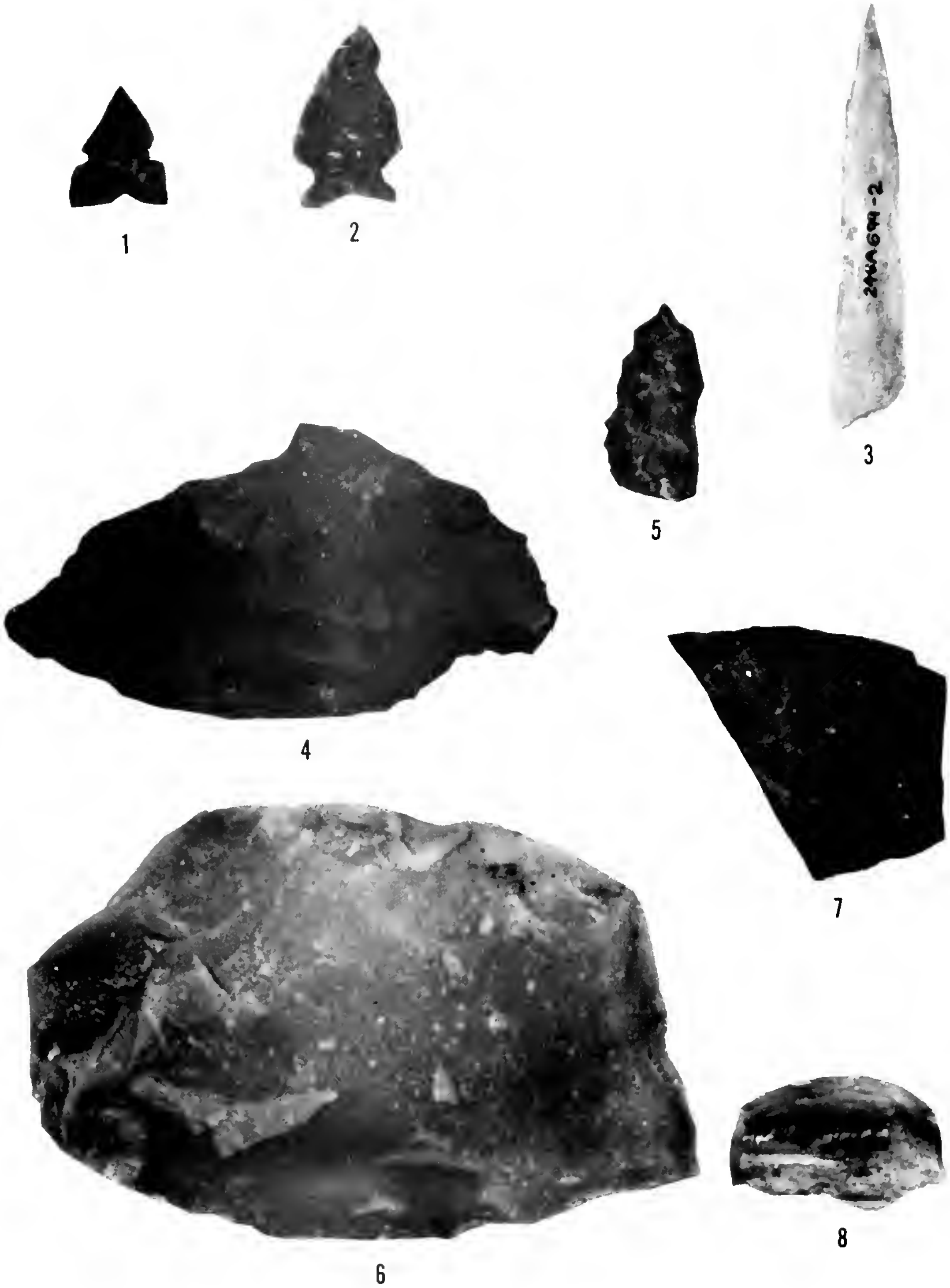

Fig. 13. Artifacts from the Corey Springs (Davis and Darroch, Montana State University) Collection.

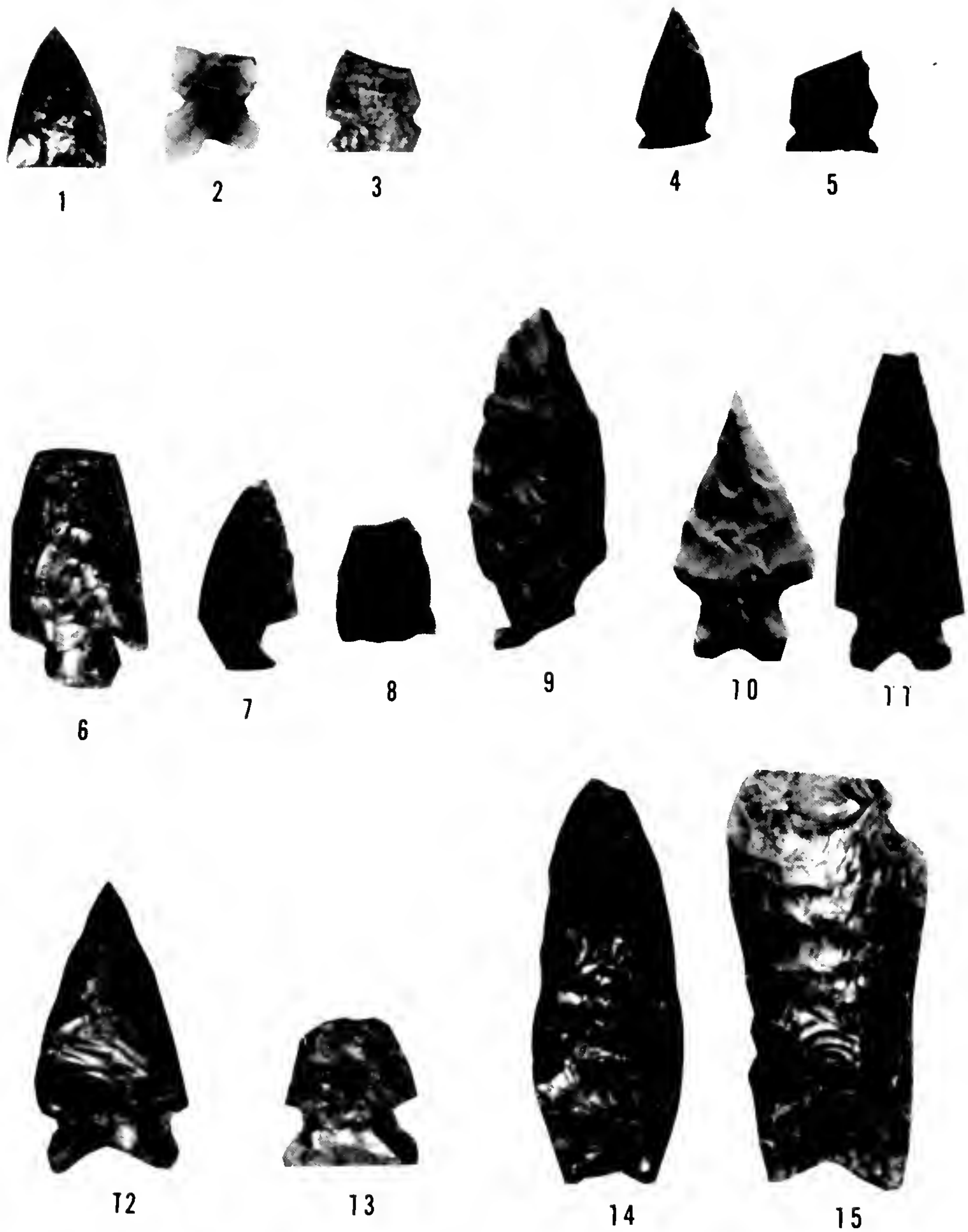

Fig. 14. Artifacts from the Red Canyon Fan-Narrows Site (24GA101) (Woodard and Montana State University) Collections, Projectile Points.

Fig. 15. Mounded Fire-Cracked Rock Feature at the Narrows in 1960 (Woodard Photo).

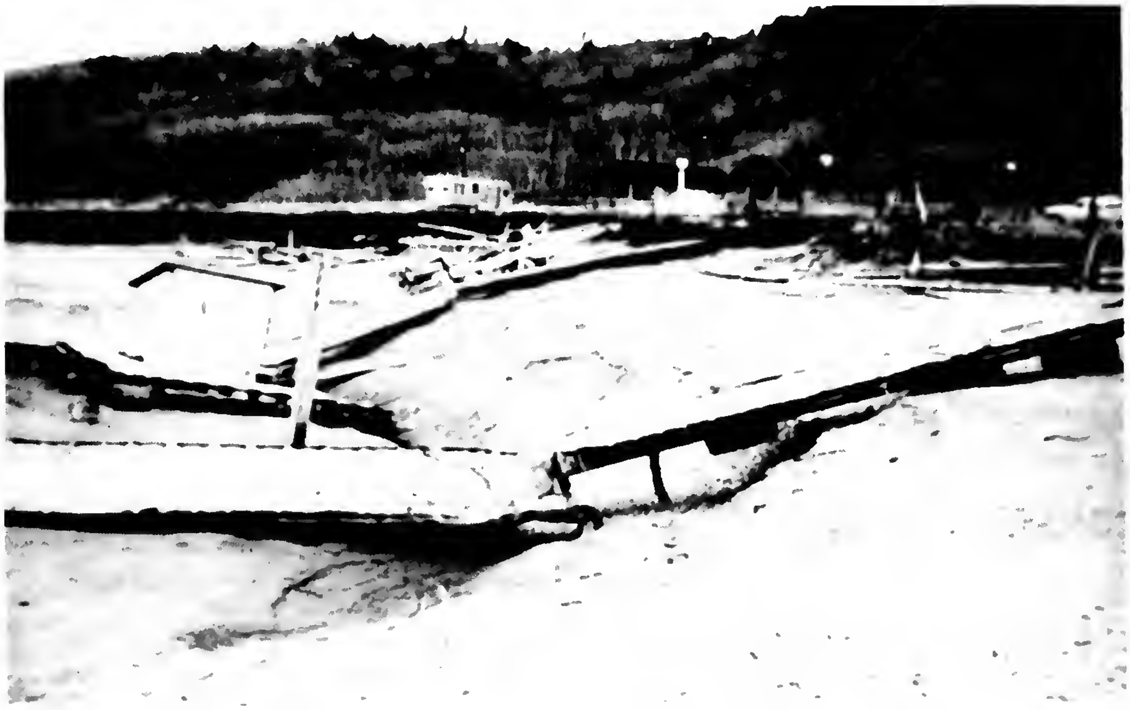

Fig. 16. Beach and Docks Exposed at the Narrows in 1960 (Woodard Photo).

Fig. 17. Cultural Bone from the Hebgen-Red Canyon Creek Area.

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APPENDIX I

GRAYLING

John N. DeHaas, Jr., Architect
Preservation and Restoration Consultant

Grayling, now deserted, cannot be classified as a "ghost town" or as an early Montana mining camp. It was, however, established long before the town and post office at Yellowstone (West Yellowstone).

Grayling was designated as a fourth class post office by order of Charles Emory Smith, Postmaster General, on October 29, 1898. Mrs. Lulu Burelle Kerzenmacher was appointed postmistress and served in that capacity until her retirement in 1942. Her son, Walter Kerzenmacher, served as acting postmaster until 1947 when he was appointed postmaster. He was postmaster for nine years until Grayling, together with a number of other fourth class post offices, was phased out of existence.

The first mail was brought to Grayling by Dick Murray. Local residents, all homesteaders, took turns bringing the mail from Henry's Lake, Idaho, 24 miles away. Mail was brought by horseback except during the winter when it traveled by dog sled. Service was extended to West Yellowstone in 1908 when the railroad built a depot there that started the town.

The home of Mrs. Kerzenmacher served as the post office in the beginning. Her son, Walter, was born in this house in 1907. In 1912 orders from Washington required that the post office be housed in a separate building and a 12 foot by 19 foot one story log cabin was built for this purpose.

The home and post office were originally located approximately a mile and a half south of their present location. They were moved in 1914 when Montana Power Co. built the dam and the water level began to rise in Hebgen Lake. Most of the buildings that surround the main house at its present location were moved there from the old homestead or were moved in from other locations about that time. The barn and boat house were built new in 1914. In 1950 the post office was moved from the small log building to the house where Walter Kerzenmacher now lives.

The main house rests upon a stone foundation lacking mortar to hold the stones. This is similar to the foundation that supported the house at its original homestead site. After being moved an addition was constructed on the north to accomodate hunters and fishermen who were boarded here. The building was then referred to as Grayling Inn.

To the north and slightly east of the main building there is a long one-story cabin divided in the middle. Each section has its own door in the gable end and its own wood stove. Its roof members are rather typical of log construction of this era. The logs run parallel to the length of the building and the ridge pole. This allows for either split poles or milled lumber to span the distance between members, forming the roof plane. These logs project beyond the end walls and form the overhang at the gable ends.

Walter Kerzenmacher states that he attended the Grayling school from the first to the seventh grades. The Grayling school was built ca. 1910-1912 and is located near Grayling Creek several miles east of the Grayling post office.

The thirteenth Census of the U.S. (1910) gives the population of Grayling (Dist. 63) as 164, and the 1920 census lists the population as 48. Yellowstone (now West Yellowstone) was called Riverside in 1910 and had a population of 40. In 1920 Yellowstone had a population of 56. The censuses of 1910 and 1920 were made by school districts. The Fifteenth Census was tabulated by voting precincts and Grayling is not listed but West Yellowstone had a population of 406. Montana, A State Guide Book, published in 1939, describes Grayling as a lonely post office near one extremity of the lake with a population of 5. Grayling was never a town in the usual sense of the word, with businesses, churches, etc. It was a post office serving homesteaders scattered over the area and as transportation facilities improved population cluster developed at West Yellowstone rather than at Grayling.

The original two-story log cabin of Postmistress Kerzenmacher now stands among a group of log cabins about a quarter mile north of highway 287. The building faces south towards Hebgen Lake, as do most of the remaining buildings including the barn which is still in use. Several of the other log buildings face east and one small log cabin, the wash house, faces north toward the creek that runs nearby. The small building which was originally utilized as a post office stood near the house but has since been moved to its present site near the barn.

When the water level of the lake reaches a low point the old foundations of the house can still be seen. The house was taken apart log by log and numbered so that it could be reassumbled at its present location. After it was moved in 1914 an addition was built on the north and later a front porch was added. This porch has since collapsed.

There are basically three types of log construction here. In one, shown in the Kerzenmacher home and the post office cabin, the logs are hewn on the top and bottom while the sides are left in their original round shape. The hewing gives joints which are tighter and need less chinking. The notching, or corner intersection, of the main house and most of the other buildings is V-notched round log, with the top of the log shaped to a point and an inverted V notched out of the bottom. No nails are needed in this method of construction and it would lend itself easily to dismantling and re-assembly.

A second construction method noted was a squared half-notch intersection of logs at the corners. This is evident on the wash house and one unit (the central one) of the dairy barn. This barn appears to have been built in three stages.

Another cornering detail noted in several of the buildings differs radically from the other two methods found. In this case the logs do not intersect at all but are cut, the ends are squared, and held together by two-by members that are joined at a 90° angle, forming a recess at the corners. The two-by members are full cut, planed lumber measuring a full two inches in thickness and varying in width (to adjust to the width of logs used) from six to eight and ten inches. These planed boards are nailed to the logs. Slightly shorter lengths of logs can thus be used and it does eliminate the need and work of notching. Of course this method of construction presupposes the availability of planed lumber--a saw mill not too far away--and nails.

All of the buildings are of a simple gable-ended roof type. In one case knee braces were used to support a rather large overhang of the roof. This is on the milk house adjacent to and just west of the main building.

Although the buildings are not inhabited today they are in relatively good condition considering the long period of neglect. All of the buildings lack a permanent foundation but none of them are leaning due to rotting of the bottom or foundation logs. The barn has a stone foundation without mortar like the main house. Two buildings, the milk house and the north section of the dairy barn (obviously the last addition to the building) have a concrete floor and foundation. Daylight can be seen through the roofs and none of these are weather-tight except the barn. Rotting or general structural failure of the roof members is not evident.

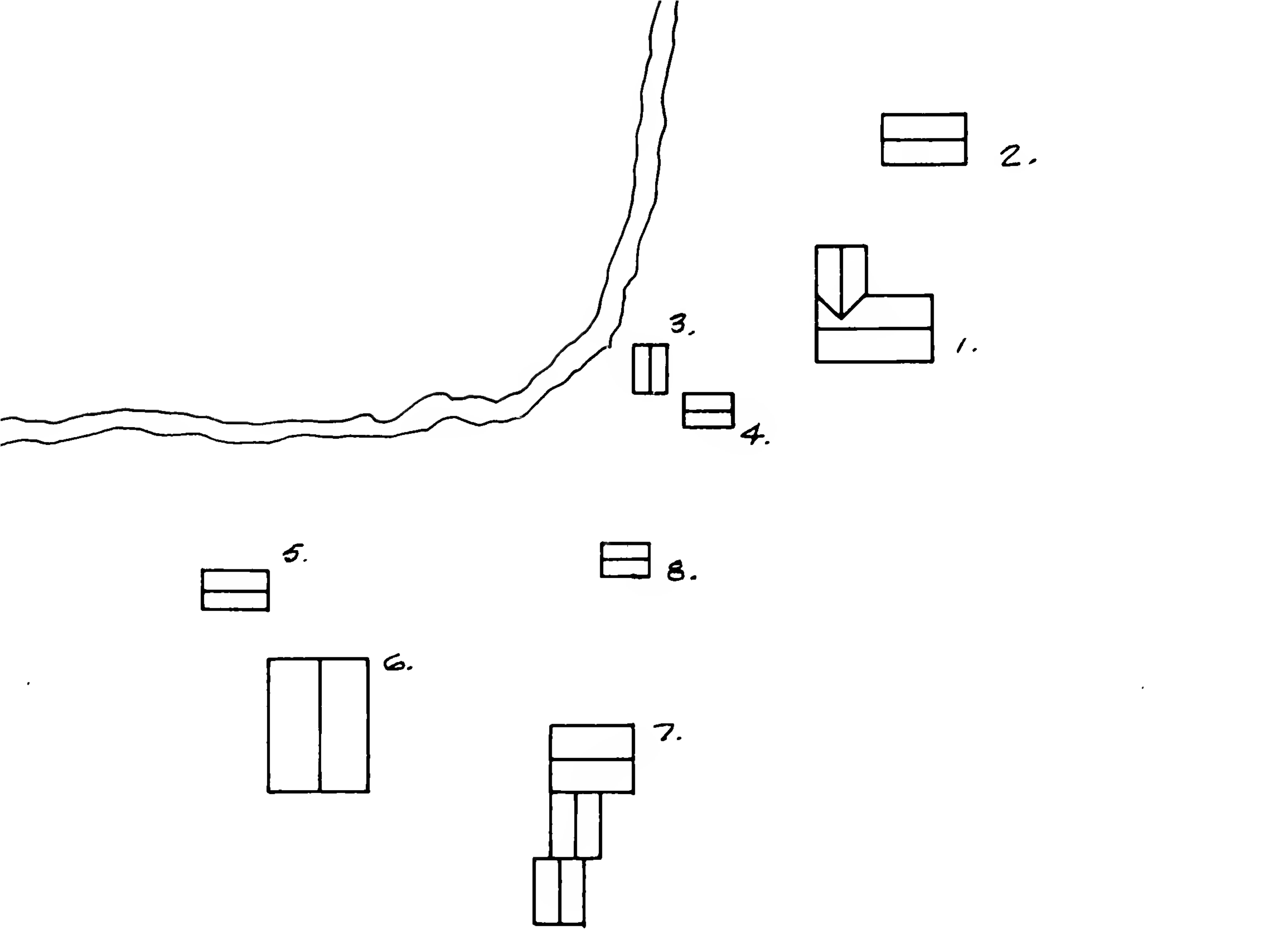
The original buildings are housed in a fenced-in area. There are other cabins erected in the last twenty years that are standing just outside the fenced-in area and are oriented facing south. These latter buildings have no historical, architectural or esthetic value.

The original grouping of buildings within the enclosed area do have historical, architectural and esthetic values. Historically they represent homestead structures erected in this part of the state in the late 1890's and early 1900's. It was not gold and silver that brought settlers to this valley but agriculture.

Architecturally the buildings are representative of log construction of the period mentioned. Earlier in this report I have discussed the various types of log construction found here.

Esthetically or pictorially, the buildings are in a pleasant setting with the mountains to the north forming a beautiful background. There is little in the area to compare with this picturesque grouping of early log cabins.

Although the buildings lack windows and doors they are in remarkably good condition and are suitable for either preservation--which should be the minimal course of action--or restoration. Basically, preservation would be the re-roofing in a manner harmonious with the buildings' vintage to prevent future damage. Restoration would be the restoring of the buildings to a liveable or useful state. Both projects would necessitate the services of a consultant trained in this area.



1. Kerzenmacher house -- Grayling Inn

2. Double cabin -- rental unit for hunters & fishermen

3. Wash house

4. Milk house

5. Post office

6. Horse barn

7. Dairy barn

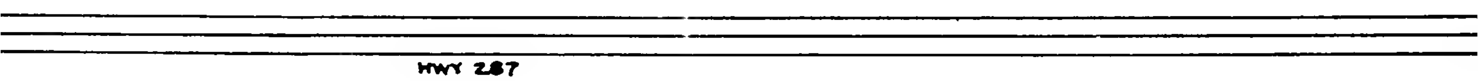
8. Boat house

N

GRAYLING MONTANA

5 5 10 10 20 20 40

SCALE IN FEET



Kerzenmacher Home -- the Grayling Inn
viewed from the northeast looking
southwestward

photo by DeHaas

Kerzenmacher Home -- the Grayling Inn
viewed from the southeast looking
northwestward

photo by DeHaas

Double Cabin -- rental unit for hunters
& fishermen; view looking north

photo by DeHaas

Milk House
viewed from the southeast looking northwestward

photo by DeHaas

Horse Barn
viewed from the southeast looking
northwestward

photo by DeHaas

Post Office
viewed from the southeast looking northwestward

photo by DeHaas

Log Corner Construction Detail, Main House

photo by DeHaas

APPENDIX II

Prehistoric Utilization of Obsidian in the Hebgen Lake-Red Canyon Creek Locality, Gallatin County, Montana

No time and/or cultural diagnostic artifacts were gathered during the 1973 site reconnaissance of the Ski Yellowstone, Inc. defined project area. The excellent Stovall collection was made available for inclusion into the project report. The numerous projectile points therein were invaluable in combination with illustrations drawn from the Corey Springs (Napton 1966: Fig. 24) site (Fig. 12) and with photographs of artifacts from the Woodard collection (Conner 1960, 1961) (Fig. 14), in establishing a locality specific chronology of prehistoric cultural activity.

Due to the virtual absence of time/culture diagnostic information from the On-Site development area proper, the company provided funds by which 122 archaeological obsidian specimens were measured for hydration preliminary to calculating the hydration ages of the specimens (Figs. 18 and 19). Nancy Marshall of the Pennsylvania Obsidian Hydration Dating Laboratory (9831 West Sidehill Road, North East, Pennsylvania 16482) made the thin sections and provided the hydration rim measurements (Table 6). In addition to developing a hard core of empirical temporal data for description purposes, this effort was expected to yield information useful in establishing minimal ages of terrace and

fan formation in the Red Canyon Creek area.

Davis (1970, 1972a, 1972b) established a chronology of prehistoric use of obsidian in the Gallatin, Madison and Yellowstone drainage areas and derived a rate of hydration that is adequate for present chronological purposes. The Southern Montana Montane hydration rate of 4.43 microns squared per 1000 years Before Present is applicable to the study area.

The hydration dated obsidian specimens distribute across identified sites and the Stovall collection as follows (Table 5): Y-Bother (N=23, D2425-D2426, D2431-D2432, D2371-D2380, D2382-D2390), Peterson (N=6, D2391-D2396), Upper Terrace (N=4, D2427-D2430), Hebgen Mountain (N=1, D2359), Corey Springs (N=39, D2320-D2358), Dandelion Meadow (N=1, D2381), Lake Shore (N=6, D2365-D2370), Narrows Spit (N=5, D2360-D2364) and Rainbow Point and environs (N=37, D2521-D2529, D2397-D2424).

Figs. 18 and 19 display the majority of the tools that were dated. The pictured specimens, all of which are from Rainbow Point and environs, are arranged in chronological order from most recent (Fig. 18, No. 1) to the earliest (Fig. 19, No. 14). Table 5 keys into the illustrations as follows: Fig. 18, No. 1 (D2403), 2 (D2407), 3 (D2416), 4 (D2528), 5 (D2422), 6 (D2524), 7 (D2424), 8 (D2521), 9 (D2408), 10 (D2529), 11 (D2413), 12 (D2523) 13 (D2525), 14 (D2412) and 15 (D2399);

Fig. 19, No. 1 (D2527), 2 (D2418), 3 (D2347), 4 (D2409), 5 (D2526), 6 (D2420), 7 (D2421), 8 (D2401), 9 (D2414), 10 (D2419), 11 (D2398), 12 (D2406), 13 (D2400) and 14 (D2405). The pictured specimens range in hydration age from 977 to 10, 562 years Before Present.

Fig. 20 displays the 122 hydration measurements in terms of their frequency distribution occurrence in .20 micron class intervals per site. The graph also shows the corresponding culture phase or complex to which all hydration measurements relate. The composite hydration profile at the right end of the figure shows the relative distribution of measurements across the three prehistoric culture intervals recognized in the area. Obsidian utilization, as expressed in the study area, was essentially continuous from Agate Basin times through the Old Women's phase at the terminus of regional prehistory. It follows that the area was inhabited intermittently but repeatedly throughout the nearly 11,000 year span of prehistoric activity known for the region. Fourteen percent of the measured specimens refer to the Early Period, while 63 percent are referrable to the Middle Period and 23 percent relate to the Late Period. This profile of relative utilization is consistent with others generated for this part of the Southern Montana Montane hydration sub-region.

The procurement of obsidian (and it s close relative ignimbrite) probably consisted of collecting nodules found

locally in substantial quantity and may have involved the actual transport of obsidian in quantity from Yellowstone and/or from sources at the west end of the Beaverhead Valley in Idaho. The importance of obsidian (and ignimbrite) is apparent in the following statistics. Analysis of the 405 waste flakes recovered during the 1973 survey reveals the following percentage distribution across lithic types (Table 4): Igneous rock - obsidian 38.7 percent, ignimbrite 21.2 percent and basalt 2.4 percent, totalling 62.3 percent; Cryptocrystalline rock - chalcedony 3.0 percent, chert 29.1 percent and jasper 2.9 percent, totalling 35 percent; Coarse Crystalline Sedimentary rock - quartzite 2.0 percent; and miscellaneous rock types such as opalized wood, mudstone and slate 0.7 percent. Despite the small sample size, this distribution is probably representative of the stone selection preferences typical of locally adapted and more transient prehistoric populations that frequented the study area.

Analysis of the hydration data from those sites at some distance from the original Madison River drainage basin proper, as opposed to those data drawn from close proximity sites, reveals an informative pattern. Hydration data from the Peterson, Upper Terrace, Hebgen Mountain and Dandelion Meadow sites are no earlier than middle Pelican Lake phase in age (ca. 2500 years); the notable exception to this fact is the Y-Bother site where

obsidian use initiates significantly earlier and persists with several interruptions into and through Pelican Lake times.

Obsidian use profiles from Corey Springs, Narrows Spit and Rainbow Point and environs have a strikingly different distribution. All of these sites are roughly at similar distances from the original drainage basin but they obviously played roles of importance as areas of brief settlement, possibly as hunting base camps. These locations saw repeated use over thousands of years (with the exception of this part of the Narrows Spit that was occupied only from late Early to middle Middle prehistoric time). It seems reasonable to conclude that there may have been a change in the spatial distribution of big game or a shift in the seasonal exploitation of the big game that occurred around 2500 years ago. Previously established hunting or settlement patterns (typical of populations that used obsidian at least) may have been elaborated in response to these circumstances or others.

At any rate, sites in the upper part of the fan were occupied essentially during the past 2500 years. Y-Bother was occupied measureably since Hanna phase times 500 years earlier. The culture-bearing sediments at Y-Bother are, unfortunately, very shallow so that 3000 plus years of cultural activity are compressed into a single, inseparable, buried cultural unit.

This approximately 40 cm. unit of colluvial-alluvial sediment represents recent accumulation. The multiple terraces evident at Y-Bother could not be distinguished in terms of different ages of accumulation due to the very small sample of obsidian that was recovered from the lower terrace.

Obsidian recovered from the eroded surface of the western-most abandoned channel of Red Canyon Creek at the Peterson site was synchronous with buried obsidian excavated from the Upper Terrace site. Obsidian was recovered from 60 cm. at the Upper Terrace site, but extensive rodent burrowing may have had a major disturbing effect on these deposits. Again, unfortunately, no obsidian was recovered from the Peterson site in Test A where cultural evidence was found to a depth of 150 cm. The overlying hearth at 50 cm. could be dated by the radiocarbon method to ascertain the age of that feature and rate of alluvial accumulation in the channel until its abandonment.

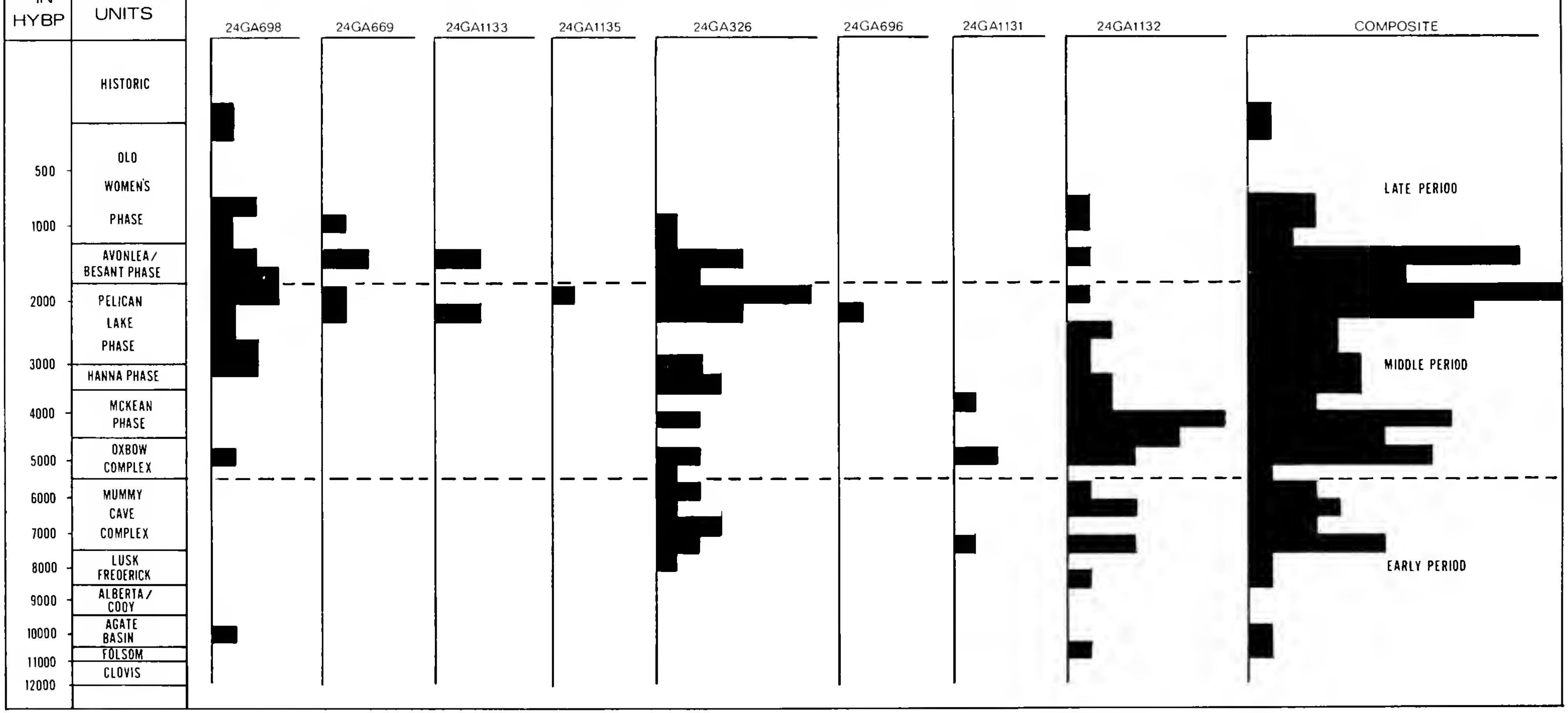
The lack of good provenience control on the features and artifact observed by Woodard along the Narrows and eroding from the fan edge prohibits any detailed age estimation at that location. One to 1.5 meters of alluvium could have conceivably accumulated over the past 4000 to 5000 years at that location without adding much to our understanding of fan formation and interim episodes of prehistoric land use.

Further work is needed quite obviously to test the possibilities suggested by the hydration dates.

Fig. 18. Hydration Dated Archaeological Obsidian Specimens, I.

Fig. 19. Hydration Dated Archaeological Obsidian Specimens, II.

FIG. 20 · HEBGEN-RED CANYON CREEK LOCALITY HYDRATION CHRONOLOGY



IV. Landscape Characteristics and Recreation Resources

L A N D S C A P E   C H A R A C T E R I S T I C S

Beardsley, Davis Associates, Inc.

INTRODUCTION

The purpose of the visual analysis was to identify and evaluate the significant visual elements of the Ski Yellowstone area in order to achieve an harmonious balance and attractive visual relationship between the existing landscape and the proposed development. Principal considerations in the aesthetic evaluation of landscape quality of the study area include the visual analysis and visual sensitivity evaluation.

VISUAL ANALYSIS

The aesthetic quality of the landscape was evaluated in terms of the following criteria:

A. Topography
B. Orientation
C. Presence of foreground features and edge conditions
D. Quality of use

Figure 1 indicates the six major landscape elements identified as being unique in character relative to the study area.

A. West lower hillside

This area is characterized by an upper boundary defined by the tree edge and a lower boundary defined by the toe of the slope. From this area one can experience excellent views of the alluvial fan area to the south, Lake Hebgen, the rolling terrain south of the Grayling Arm of Hebgen Lake, as well as a panoramic view of higher mountains of the Continental Divide to the southwest.

B. East lower hillside

Although this area in many ways is similar to the west lower hillside zone, it is distinguished by more significant views of the Continental Divide to the southwest and views to the north of Kirkwood Ridge.

C. Meadows at the north end of the alluvial fan

The character of this area is distinguished primarily by the enclosed and intimate landscape formed by the hillsides and tree vegetation to the east and west. Topography of both creek channels adds interest as well as vistas to the south of Hebgen Lake and to the north of Kirkwood Ridge.

D. Upper Red Canyon Meadows

Enclosed, small scale landscape elements of local significance. No major vistas are apparent from this location.

E. Mt. Hebgen south facing slopes

This zone is the most exposed of those described with respect to views from Highway 287. It is characterized by rolling topography and vegetation with numerous openings in tree canopy revealing views to the east, southeast, and southwest of the Continental Divide and Hebgen Lake. From the top of this zone, Yellowstone Park is also visible, as are views of Kirkwood Ridge

F. Mt. Hebgen east facing slopes

This zone is characterized by more uniform and dense tree vegetation with several clear cut areas. The views are limited to the southeast of the lake and alluvial fan and to the wooded slopes on the east side of the drainage. Occasional views of the Red Canyon Earthquake Fault Scarp are also apparent from this location.

In addition to the above landscape elements which are of relative unique character, other areas more uniform in character were also identified. These zones are characterized by lack of foreground features and edge conditions as well as comparatively uniform topography.

A. Alluvial fan area

Within the study area the alluvial fan is most dominant as having uniform character. Generally characterized by minor physiographic diversity and grassland vegetation, this zone becomes more interesting within the northern portion where the valley narrows and becomes more defined by the hillside. From this zone there are interesting views in all directions, the most significant of which is the view of Hebgen Lake. Of equal interest is the historic Grayling Village.

VISUAL SENSITIVITY

Investigations of the Ski Yellowstone area revealed the presence of the following principal observer corridors.

A. Views from Highway 287 traveling west;
B. Views from Highway 287 traveling east;
C. Views from the proposed gondola alignment;
D. Views of the proposed village;
E. Views of the ski slopes from proposed village and;
F. Views from the proposed village location of Hebgen Lake and the south shore.

Views to the observer from each of these vantage points were recorded, analyzed, and evaluated in terms of the following categories of visual sensitivity based on the type of observed landscape and viewing distance.

A. High scenic value foreground and high scenic value middle ground equals high visual sensitivity.

B. Low scenic value foreground equals moderate visual sensitivity.

C. Low scenic value middle ground equals low visual sensitivity.

Viewing distance was defined as follows:

A. foreground = 0 - 1/2 mile

B. middle ground = 1/4 - 3 to 5 miles

C. background = 3 - 5 miles to infinity

Scenic values were evaluated in terms of diversity, variety, color, form, scale, and texture. The presence of edges between different landscape components, unique natural features, as well as features of historic and cultural significance were also evaluated: in terms of their scenic value.

Although the effect of seasons on the landscape was not considered in substantial detail, it can generally be said that the winter season tends to unify this landscape (e.g. the Lake will be difficult to recognize and blends with the flat area of the alluvial fan), and the spring and fall seasons will reveal a higher degree of diversity in the landscape.

VISUAL SENSITIVITY SUMMARY

The degree of visual sensitivity was derived by applying the following factors to areas identified as being sensitive:

A. High visual sensitivity = 3

B. Moderate visual sensitivity = 2

C. Low visual sensitivity = 1

In addition to these factors, the number of observers with respect to each corridor was estimated and taken into consideration as well as an estimate of the average observation time with respect to each individual corridor. The following summary indicates the results of this evaluation in terms of high, moderate, and low visual sensitivity.

Generally the most important observer corridors or vantage points were identified as the proposed village development, the Gondola Corridor and ski slopes. Views of Mount Hebgen from the Highway 287 Corridor traveling west were considered to be of moderate importance with principal interest being directed towards the southwest facing slope of Mt. Hebgen and the proposed Gondola. The remaining corridors were identified of little significance due to the low number of observers and relatively short observer viewing times.

FINDINGS AND RECOMMENDATIONS

The findings and recommendations of the visual analysis are discussed in terms of the three following areas of visual sensitivity and are illustrated in Figure 2.

A. Areas of high visual sensitivity are those defined as being of high scenic value (foreground and middle ground) together with relatively high number of observers and relatively long observation time.

B. Areas of moderate visual sensitivity are characterized by a low number of either scenic value, the number of observers, or the duration of viewing time.

C. Areas of low visual sensitivity are characterized as being low in more than one of the categories of scenic value, number of observers, and duration of viewing time.

Areas identified as being high in visual sensitivity:

- Lake Hebgen shoreline
- The two main creek channels of Red Canyon Creek
- Lower portions of the southeast facing ski slopes together with the west facing slope of Red Canyon drainage
- The area on both sides of the proposed Gondola line
- The top of Mt. Hebgen
- The northern portion of the alluvial fan of Red Canyon Creek

Areas identified as being moderate in visual sensitivity:

- Balance of the alluvial fan
- The balance of proposed ski trails
- The area in the vicinity of the Grayling Creek delta

Areas identified as being low in visual sensitivity:

- Outside the immediate project area

MITIGATION OF POTENTIAL VISUAL IMPACT

The following recommendations are suggested for mitigating the potential visual impact by proposed development.

A. The shoreline of Hebgen Lake and Red Canyon Creek channels should be either retained in their original state or enhanced by means of a careful landscape plan and planting program.

B. Clearing for the Gondola should not be a "hard edged" corridor, but rather, should be designed and constructed so that the edges are "feathered" with the clearing blending in a natural way with existing open areas and glades. If the Gondola line is high enough, possibly a minimal amount of clearing can be considered or avoided in certain areas and still conform to safety standards.

C. All ski slopes in terms of location and configuration should be designed in such a manner that trail clearing and construction methods are designed and implemented in as natural a manner as possible, still permitting adequate skier flow and safety. Design measures such as feathering the trail edges, glading, and sensitive lift line clearing, should be considered so that these elements blend in as natural a way as possible with the existing open areas. Wherever possible, existing large trees or clumps of trees should be maintained.

D. The southwesterly facing slopes within the study area should be left in their natural state as the lower portions of these slopes are particularly subject to adverse visual impact due to the exposed orientation and lack of vegetation.

E. The proposed village site will be very exposed to the maximum amount of observers both from west bound Highway 287 travelers and from the mountain. Given that exposed nature, development should be designed and carefully integrated with the open character of the grassland and sagebrush areas. Hopefully, major portions will be preserved in their natural state.

   Careful consideration should be given to the interplay of concentrations of development and open space with particular attention to colors appropriate and indigenous to the area. Of particular importance will be the overall "roof-scape" of the village when viewed by skiers from the mountain.

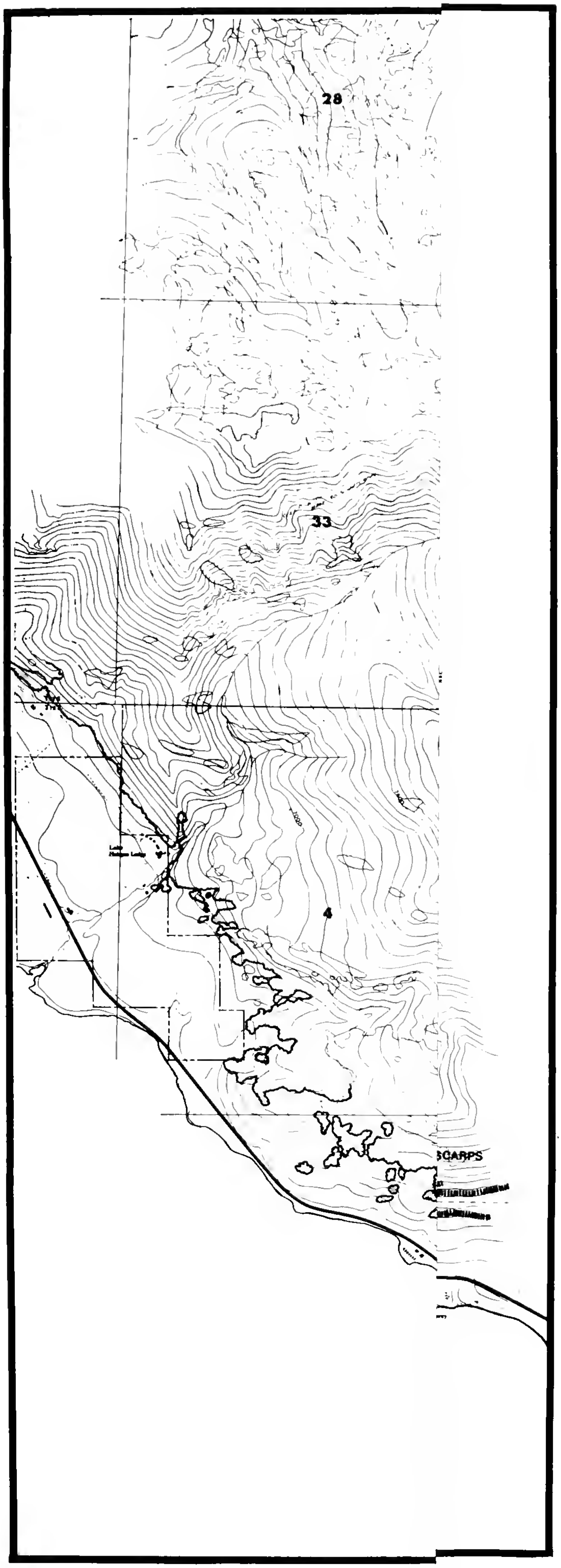


FIGURE 1

ENVIRONMENTAL SUMMARY

PRIMARY STUDY AREA

SCENIC RESOURCES

VISUAL ANALYSIS

BY BEARDSLEY, DAVIS ASSOC. INC.

LANDSCAPE UNITS OF UNIQUE CHARACTER AND HIGH VISUAL QUALITY

OPEN BOUNDARY

AREAS OF UNIFORM CHARACTER

VALUABLE FOREGROUND:
- TREE EDGES
- CREEK BEDS
- WATER EDGE

UNIQUE LANDSCAPE FEATURES:
- FAULT SCARPS
- ROCK OUTCROP

STRUCTURES OF HISTORIC INTEREST

SIGNIFICANT VIEWS

FAR VIEWS OF HIGH QUALITY

FAR VIEWS OF LESSER QUALITY

NEAR VIEWS OF HIGH QUALITY

NEAR VIEWS OF LESSER QUALITY

SKI YELLOWSTONE

SKI YELLOWSTONE INC.

WEST YELLOWSTONE, MONTANA

SCALE. 1" = 2000'

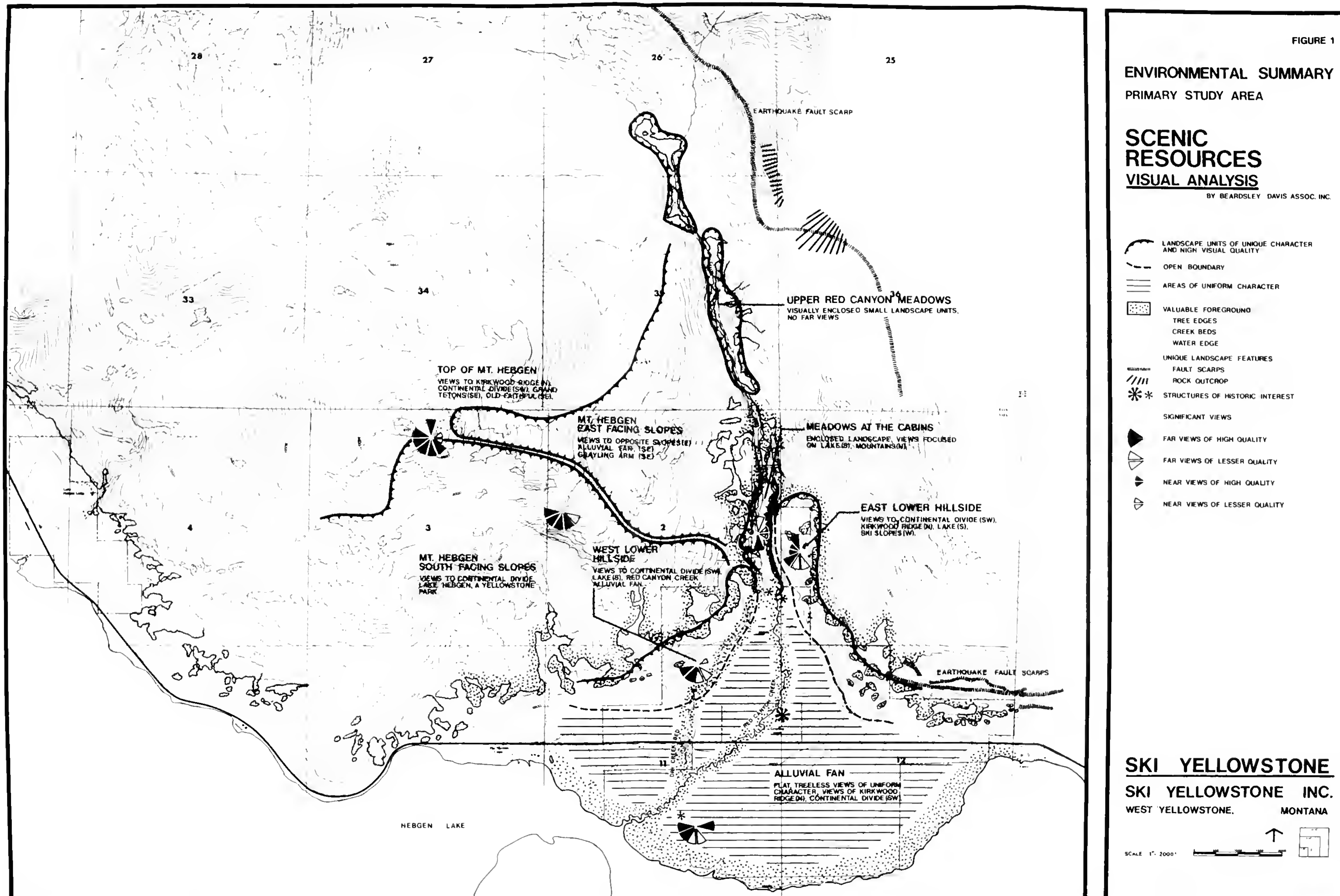


FIGURE 1
ENVIRONMENTAL SUMMARY
PRIMARY STUDY AREA
SCENIC RESOURCES
VISUAL ANALYSIS
BY BEARDSLEY DAVIS ASSOC. INC.
LANDSCAPE UNITS OF UNIQUE CHARACTER AND HIGH VISUAL QUALITY
OPEN BOUNDARY
AREAS OF UNIFORM CHARACTER
VALUABLE FOREGROUND
TREE EDGES
CREEK BEDS
WATER EDGE
UNIQUE LANDSCAPE FEATURES
FAULT SCARPS
ROCK OUTCROP
STRUCTURES OF HISTORIC INTEREST
SIGNIFICANT VIEWS
FAR VIEWS OF HIGH QUALITY
FAR VIEWS OF LESSER QUALITY
NEAR VIEWS OF HIGH QUALITY
NEAR VIEWS OF LESSER QUALITY
SKI YELLOWSTONE
SKI YELLOWSTONE INC.
WEST YELLOWSTONE, MONTANA
SCALE 1" 2000'
28
27
26
25
33
34
36
4
3
2
11
12
EARTHQUAKE FAULT SCARP
UPPER RED CANYON MEADOWS
VISUALLY ENCLOSED SMALL LANDSCAPE UNITS, NO FAR VIEWS
TOP OF MT. HEBGEN
VIEWS TO KIRKWOOD RIDGE (N), CONTINENTAL DIVIDE (SW), GRAND TETONS (SE), OLD FAITHFUL (SE).
MT. HEBGEN EAST FACING SLOPES
VIEWS TO OPPOSITE SLOPES (E) ALLUVIAL FAN (SE) GRAYLING ARM (SE)
MEADOWS AT THE CABINS
ENCLOSED LANDSCAPE, VIEWS FOCUSED ON LAKE (S), MOUNTAINS (N)
EAST LOWER HILLSIDE
VIEWS TO CONTINENTAL DIVIDE (SW), KIRKWOOD RIDGE (N), LAKE (S), SKI SLOPES (W).
WEST LOWER HILLSIDE
VIEWS TO CONTINENTAL DIVIDE (SW) LAKE (S), RED CANYON CREEK ALLUVIAL FAN.
MT. HEBGEN SOUTH FACING SLOPES
VIEWS TO CONTINENTAL DIVIDE LAKE HEBGEN, & YELLOWSTONE PARK
EARTHQUAKE FAULT SCARPS
RED CANYON CREEK
DRY CREEK BED
ALLUVIAL FAN
FLAT, TREELESS VIEWS OF UNIFORM CHARACTER, VIEWS OF KIRKWOOD RIDGE (N), CONTINENTAL DIVIDE (SW)
HEBGEN LAKE

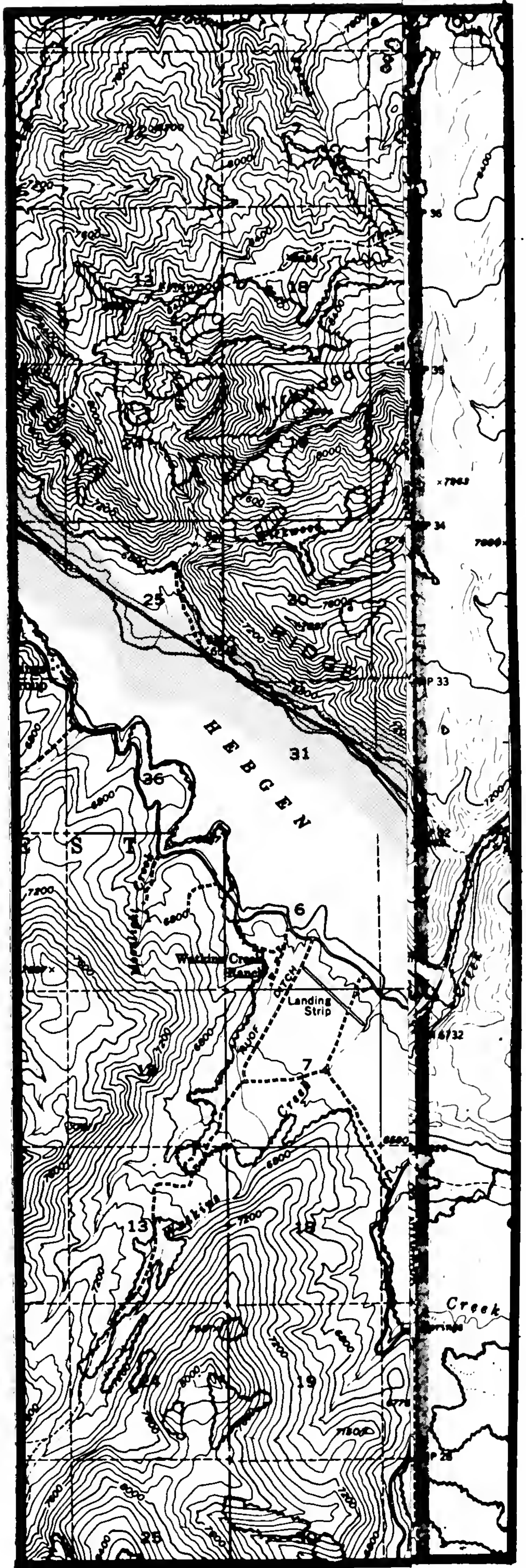


FIGURE 2

ENVIRONMENTAL SUMMARY

SECONDARY STUDY AREA

SCENIC RESOURCES

VISUAL SENSITIVITY SUMMARY

LEGEND

HIGH VISUAL SENSITIVITY

MODERATE VISUAL SENSITIVITY

LOW VISUAL SENSITIVITY

SKI YELLOWSTONE

SKI YELLOWSTONE INC.

WEST YELLOWSTONE, MONTANA

SCALE 1:62500

0 5000 10,000 FEET

0 1 2 MILES

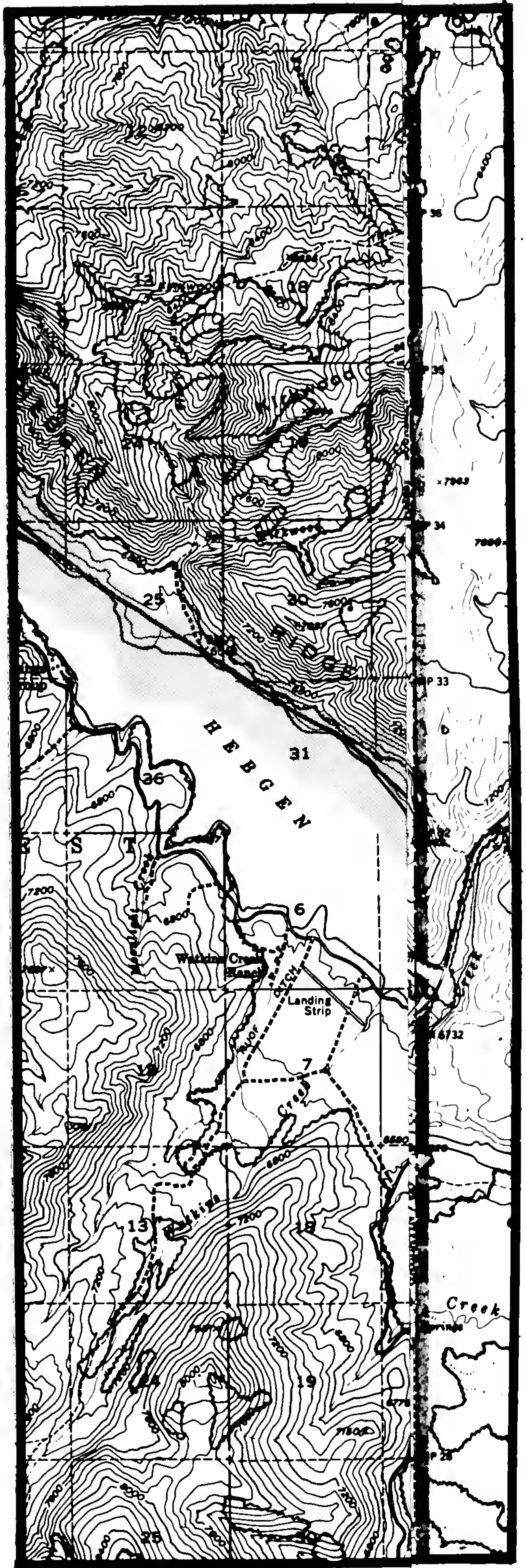


FIGURE 2

ENVIRONMENTAL SUMMARY

SECONDARY STUDY AREA

SCENIC RESOURCES

VISUAL SENSITIVITY SUMMARY

LEGEND

- HIGH VISUAL SENSITIVITY
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- LOW VISUAL SENSITIVITY

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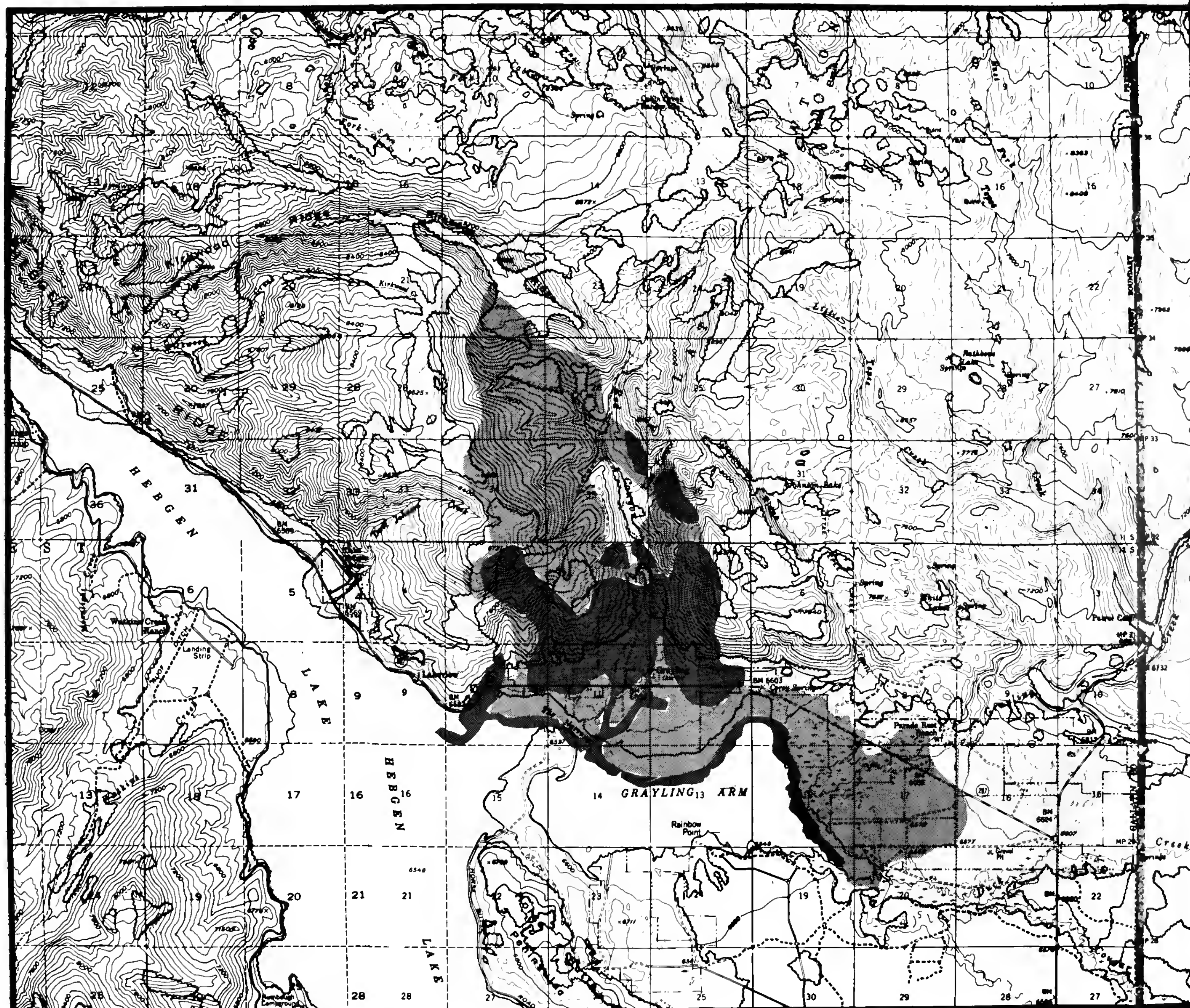

FIGURE 2

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SECONDARY STUDY AREA

SCENIC RESOURCES

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LEGEND

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SCALE 1:62500

0 5000 10,000 FEET

0 1 2 MILES

R E C R E A T I O N   R E S O U R C E S

Beardsley, Davis Associates, Inc.

EXISTING RECREATION

The present recreation resources of the Mt. Hebgen area can be classified as shown on Figure 1, using the Bureau of Outdoor Recreation's Classification System for recreation lands. The classes may be defined as follows:

Class I: High Density Recreation Areas

"Usually within or near major centers of urban population, but may occur within such units as national parks and forests remote from population concentrations...Intensive day or weekend use type (activities), such as picnicking, water sports, group field games, and other activities for many people...High degree of facility development which often requires heavy investment. They are usually managed exclusively for recreation purposes."

Class II: General Outdoor Recreation Areas

"Usually more remote than Class I areas, however, relatively accessible to centers of urban population...Included are portions of public parks and forests, public and commercial camping sites, picnic grounds, trail parks, ski areas, resorts, streams, lakes, coastal areas, and hunting preserves...Extensive day, weekend, and vacation use types..."

Class III: Natural Environment Areas

"Extensive weekend and vacation (use) types dependent on quality of the natural environment, such as sightseeing, hiking, nature study, picnicking, camping, swimming, boating, canoeing, fishing, hunting, and mountaineering. The primary objective is to provide for traditional recreation experience in the out-of-doors, commonly in conjunction with other resource uses. Users are encouraged to enjoy the resource 'as is', in natural environment."

Class IV: Outstanding Natural Areas

"Outstanding natural feature associated with an outdoor environment that merit special attention and care in management to insure their preservation in their natural condition. Includes individual areas of remarkable natural wonder,...or features of scientific importance. (Activities:) Sightseeing, enjoyment, and study of the natural features."

Class V: Primitive Areas

(None present)

RECREATION RESOURCES

Beardsley, Davis Associates, Inc.

EXISTING RECREATION

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Class V: Primitive Areas (None present)

Class VI: Historic and Cultural Sites

> "These are sites associated with the history, tradition, or cultural heritage of National, State, or local interest...(Activities:) Sightseeing, enjoyment, and study of the historic or cultural features."

PRESENT RECREATION USES:

Winter

Existing winter recreation falls into Class III - Natural Environment uses. Activities are, for the most part, limited to hiking, backpacking, camping, and, recently, ski touring. Several hiking trails and unimproved dirt roads are located in the Red Canyon Creek and Little Tepee Creek areas.

Summer

Existing summer recreation is composed largely of Class III use types, characterized by little development and a lack of improvement facilities. Activities include excellent fishing, picnicking, fairly light hunting (during the five-week season) and backpacking, hiking, camping, boating, wildlife observation, viewing of the area from the highway, and a limited amount of swimming. A few more intensive use areas, of the Class II - General Outdoor Recreation - type, are present in the form of developed campgrounds and privately owned small vacation resort developments which include, in some cases, marina facilities for boating activity use. A limited Class IV area is present in the vicinity in the form of the Red Canyon Fault Scarp caused by the Hebgen Lake Earthquake of 1959. The scarp, located in the U.S. Forest Service's Madison River Canyon Earthquake Area, is visible from Highway 287, and is identified by a USFS roadside sign.

POTENTIAL FOR RECREATION

A great potential exists for increasing recreation opportunities, as shown on Figure 2, in the form of making it possible for a vastly greater number of people to be able to make use of the Mt. Hebgen area as well as providing for a greater variety of recreation uses of this area. These may be divided into seasons and class uses as follows:

Winter

The potential for additional winter recreation in the Mt. Hebgen area exists to a great degree, but its realization depends to a great extent on the presence of development facilities or improvement of existing facilities.

Class I:

Intensive Sightseeing - potential for sightseeing exists in the form of scenic, panoramic views of such areas as Yellowstone National Park and the Tetons, which are visible from the top of Mt. Hebgen. Also, opportunities for viewing skiing activities at close range add to the winter scenic potential of the mountain itself. A method for transporting visitors up the mountain in comfort (making use of lift facilities constructed for alpine skiing activities, as described below) is necessary in order to take full advantage of this potential. The location of restaurant facilities at the top of Mt. Hebgen, with, perhaps, telescopes for viewing distant sights and descriptions of what is visible, would add variety to this experience.

Class II:

Alpine Skiing - because of snow and terrain conditions, at least one major area exists which has great potential for accommodating several thousand skiers. This area is the Mt. Hebgen slope, development (in the form of lifts and cleared runs) of which could afford a great increase in recreational opportunities. Ski school classes in technique would provide for skiers to increase their skill and therefore their enjoyment of the skiing experience, and enable beginners to learn to ski, thus enabling non-skiers to begin to take advantage of this activity.

Ice Skating - climate conditions provide for this possibility for winter recreation use of flat areas on the alluvial fan area and near Hebgen Lake.

Class III:

Ski Touring and Mountaineering - modification of existing hiking trails and the addition of improvements such as packing and maintenance of snow and trails, and, perhaps, erection of warming-huts or shelters throughout the higher country, would lead to a great increase in potential for enjoyment and opportunities for touring and mountaineering. The addition of classes in technique and skills would also provide for a greater quality of the experience. Because it possesses characteristics of varied terrain, lack of high wind, and excellent snow conditions, this area is also extremely suitable for use in cross country skiing training programs such as that for the National Cross Country Ski Team.

Hiking - the above-mentioned improvements in terrain, trails, and facilities for ski touring would also serve to enhance the potential quality of winter hiking in this area.

Backpacking - Improvement of access trails to the semi-primitive upper country north of Mt. Hebgen would also provide for an increase in opportunities for backpacking activities. A program in survival techniques and methods for protecting the environment could serve to increase enjoyment as it would increase safety and help to protect the existing quality of the area.

Camping - erection of overnight cabins, perhaps kept stocked with firewood to add to comfort and prevent ravaging of the surrounding forest, and reserved in advance if necessary, could greatly increase overnight winter use potential of more accessible areas. The improvement of access roads also would contribute to an increase in the number of people able to utilize this type of opportunity.

Class VI:

Old Grayling - this site has the potential for becoming a historic attraction year-round. A program of restoration of buildings and grounds, with the eventual development of a presentation of the cultural history of the area, perhaps including for display any artifacts found near the site, all are possibilities for enhancing old Grayling as a visitor attraction.

SUMMER

Class I:

Sightseeing - potential for summer sightseeing, with a vast effect on numbers of people able to enjoy Mt. Hebgen and views from its southeast-facing slopes and summit, will be greatly enhanced by making use of ski-lift facilities to transport visitors up Mt. Hebgen. The view from the summit encompasses Yellowstone Park including Old Faithful, the Tetons, and Hebgen Lake, while future views will also include the Ski Yellowstone development. Presence of explanatory markers, graphic displays, and/or pamphlets made available to visitors, describing visible features such as area wildlife, flowers, trees, views, and earthquake-related phenomena such as the fault scarp which is highly visible from the Mt. Hebgen summit would add to the enjoyment of casual visitors. For those more deeply interested in nature study, maps or guideposts pointing out walking trails to points of interest or through areas of natural beauty would greatly add to the quality of the sightseeing experience. A "nature trail" approach, with signposts describing flora and fauna of the area, items of geologic interest, fault scarps and the method of their formation, including background information concerning the Hebgen Lake earthquake of 1959, would enhance the visitor's appreciation of this natural area.

Class II:

Tennis, Swimming (pools), Picnicking, etc. - an increase in facilities associated with planned developments in the area for the above sports and uses would provide for an enhancement of recreational variety, as types of possible activities are increased.

Class III:

Hiking - improvement of access routes and the marking and grooming of trails would increase potential for use of the Class III areas during the summer.

Backpacking - the same improvements mentioned above would improve backpacking experiences in the area. As noted under "winter" activities, instruction in safety techniques and methods of protecting the natural environment would improve the quality of this recreation experience type.

Camping - the potential exists for increased use of the more accessible areas if, as noted above in the winter section, cabins were maintained, and access routes provided.

Boating - increased use of the abundant lake recreational resources could occur if additional marina facilities are constructed along the lake. Noise and effluent controls would be necessary, however, to at least retain the present level of quality.

Fishing - the above-mentioned marinas would serve to increase fishing potential in Hebgen Lake, as also might the presence of additional available accommodation facilities along the lake at the ski development site. Care should be taken in this case, however, to assure that over-fishing does not occur, with studies made to determine whether additional stocking is required, and, if so, of what magnitude.

Swimming (lake), Water Skiing, and other water sports - any improvement in beach facilities would lead to an increase in recreational opportunities of this type during the short season. Especially in need of improvement is the beach material itself, which is very unsatisfactory at the present time.

Horseback Riding - provision and maintenance of trails, as well as facilities for rental or boarding of horses, would provide for the possibility of an increased amount of this type of activity. Guided rides into the semi-primitive upper canyon area represents a possible recreation use, leading to further utilization of the warming huts or overnight facilities mentioned above.

Rock Climbing - areas of rock outcrops suitable for technical climbing activities exist in the Mt. Hebgen area. The possibility of a summer rock climbing/mountaineering school or camp would enhance opportunities to take full advantage of these resources.

Nature Study, Ecological Appreciation, Nature Photography - seminars, workshops, programs, or camps addressing the above topics represent real possibilities for taking advantage of the natural beauty and quality of this area.

Class IV:

Earthquake/Fault Study - programs designed to describe and explain these natural phenomena, as well as more permanent institute-type facilities, would lead to increased comprehension by casual visitors as well as additional knowledge by professionals of natural events and processes in this area.

Class VI:

Old Grayling - the same programs and displays mentioned in the "winter" recreation potential section would very definitely also provide summer recreation in the form of study and appreciation of the history and culture of the area.

POTENTIAL NEGATIVE EFFECTS

Potential decrease in some recreational uses may occur due to the development of Mt. Hebgen. Snowmobiling will, in all probability, be eliminated in the area planned to be used for skiing and ski touring. Hunting in the immediate surroundings possibly will decrease as game animals may move away from more intensively used portions of the land. However, present hunting use of this area is termed "mild", with the Canyon being utilized as access to the higher country. This access will still be available, and, quite possibly, improved after development. A slight short-term decrease in use potential of the lake-front may occur in the vicinity of the site of the marina during its construction, but this will be eliminated after its completion. Construction methods will be utilized which will keep this disturbance to a minimum.

PRESENT MANAGEMENT

The proposed Ski Yellowstone site is comprised of private land, on which the base area facilities will be located, and public (U.S. Forest Service) land, where ski trails, lifts, and some skier facilities such as a mountain restaurant, will be constructed. The public land is within the Madison River Canyon Earthquake Area of the Gallatin National Forest, and is managed by the Forest Service under a Multiple Use Charter. The focus of the area is on appreciation of the geologic phenomena associated with the 1959 earthquake, with an emphasis on recreational use. Uses which detract from geologic appreciation are not permitted; however, since no scarps exist in the proposed development area, there is no conflict where Ski Yellowstone is concerned. The presence of Ski Yellowstone will add very significantly to the diversity of recreational opportunities available in this area, and will vastly increase the numbers of people who will be able to take advantage of using the area. The presence of Ski Yellowstone will also serve to relieve regional pressures which are building up. Yellowstone National Park, located 12 miles from the development site, is currently involved in a plan to phase out a large percentage of its in-Park visitor accommodations. The Park is looking to outside developments to provide overnight space for the increasing numbers of visitors who will

continue to visit the area. As stated in the Yellowstone Master Plan, "Every encouragement and assistance should be given to the development of visitor overnight accommodations outside and within an hour's driving distance of the park."

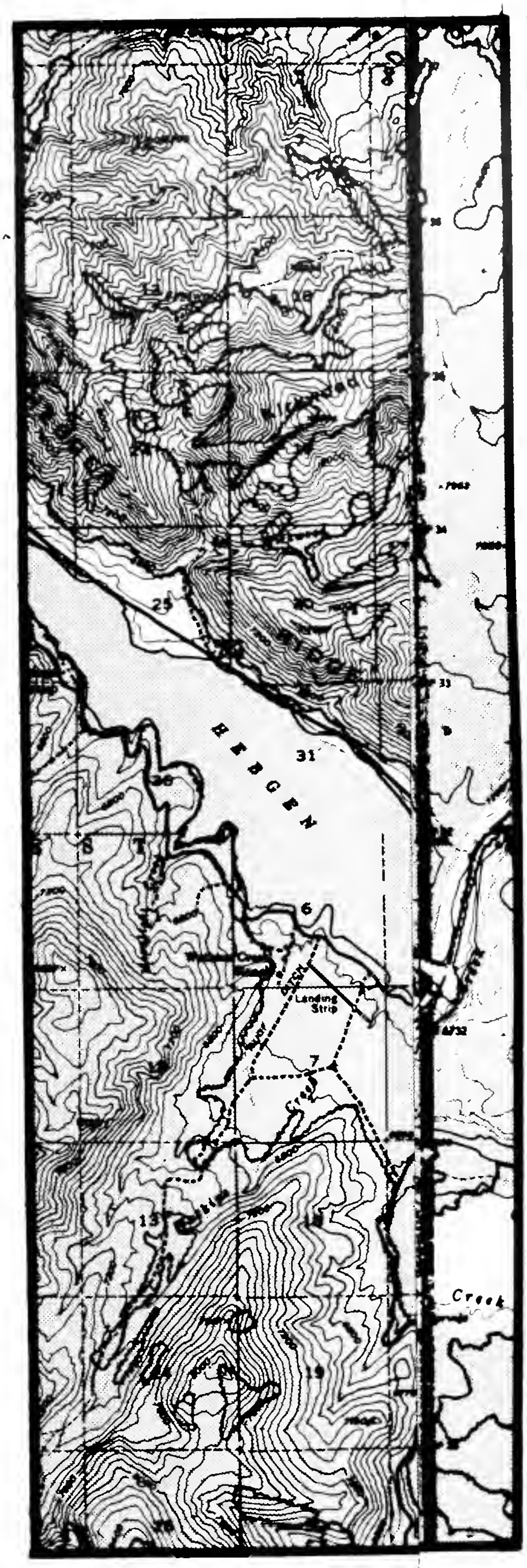


FIGURE 1

ENVIRONMENTAL SUMMARY
SECONDARY STUDY AREA

RECREATION RESOURCES

EXISTING RECREATION
--INVENTORY

LEGEND

CLASS II*
GENERAL OUTDOOR RECREATION

CLASS III*
NATURAL ENVIRONMENT

CLASS IV*
OUTSTANDING NATURAL AREAS

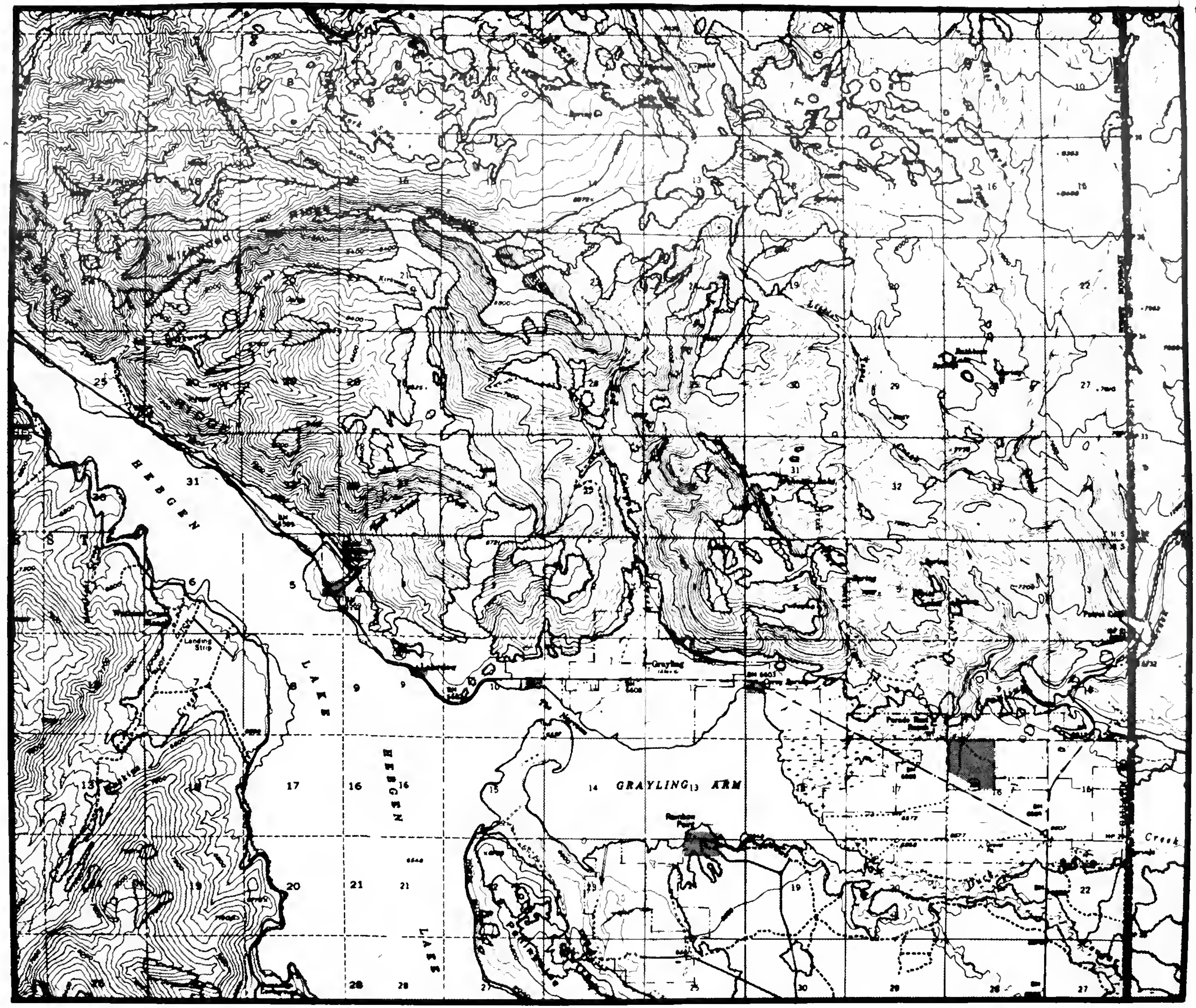
*BUREAU OF OUTDOOR RECREATION CLASSIFICATION SYSTEM

SKI YELLOWSTONE

SKI YELLOWSTONE INC.
WEST YELLOWSTONE, MONTANA
SCALE 1:62500

0 5000 10,000 FEET

0 1 2 MILES



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SECONDARY STUDY AREA

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WEST YELLOWSTONE, MONTANA

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0 5000 10,000 FEET

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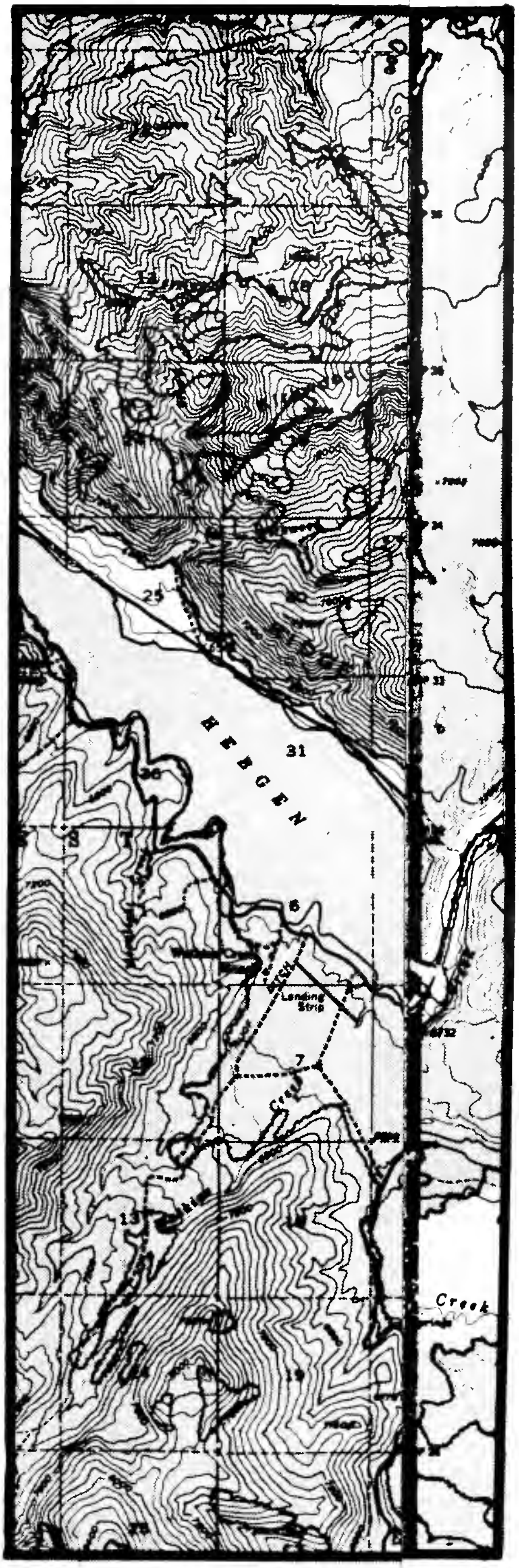
FIGURE 2



ENVIRONMENTAL SUMMARY
SECONDARY STUDY AREA

RECREATION RESOURCES

FUTURE RECREATION -- PREDICTION

LEGEND

CLASS I*
HIGH DENSITY RECREATION

CLASS II*
GENERAL OUTDOOR RECREATION

CLASS III*
NATURAL ENVIRONMENT

CLASS IV*
OUTSTANDING NATURAL AREAS

CLASS VI*
HISTORIC & CULTURAL SITES

DENOTES SIGNIFICANT INCREASE IN RECREATION OPPORTUNITIES ALTHOUGH CLASS DESIGNATION DOES NOT CHANGE

*BUREAU OF OUTDOOR RECREATION CLASSIFICATION SYSTEM

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SKI YELLOWSTONE INC.
WEST YELLOWSTONE, MONTANA

SCALE 1:62500

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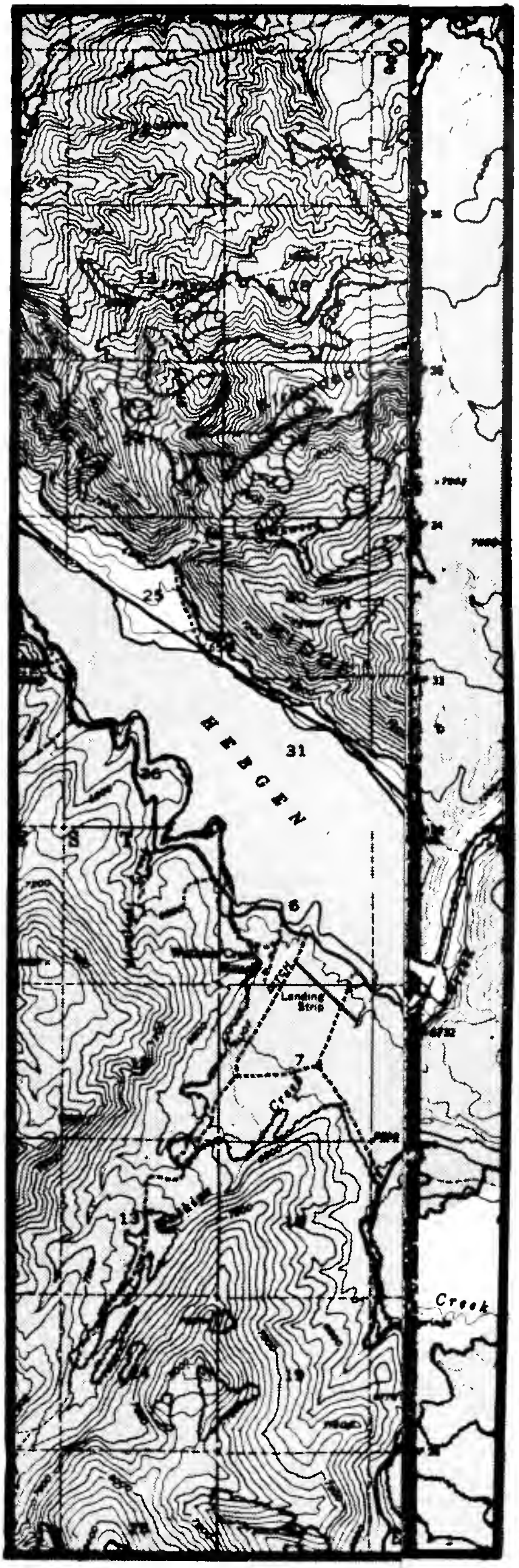

FIGURE 2

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SECONDARY STUDY AREA

RECREATION RESOURCES

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-- PREDICTION

LEGEND

CLASS I*
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CLASS III*
NATURAL ENVIRONMENT

CLASS IV*
OUTSTANDING NATURAL AREAS

CLASS VI*
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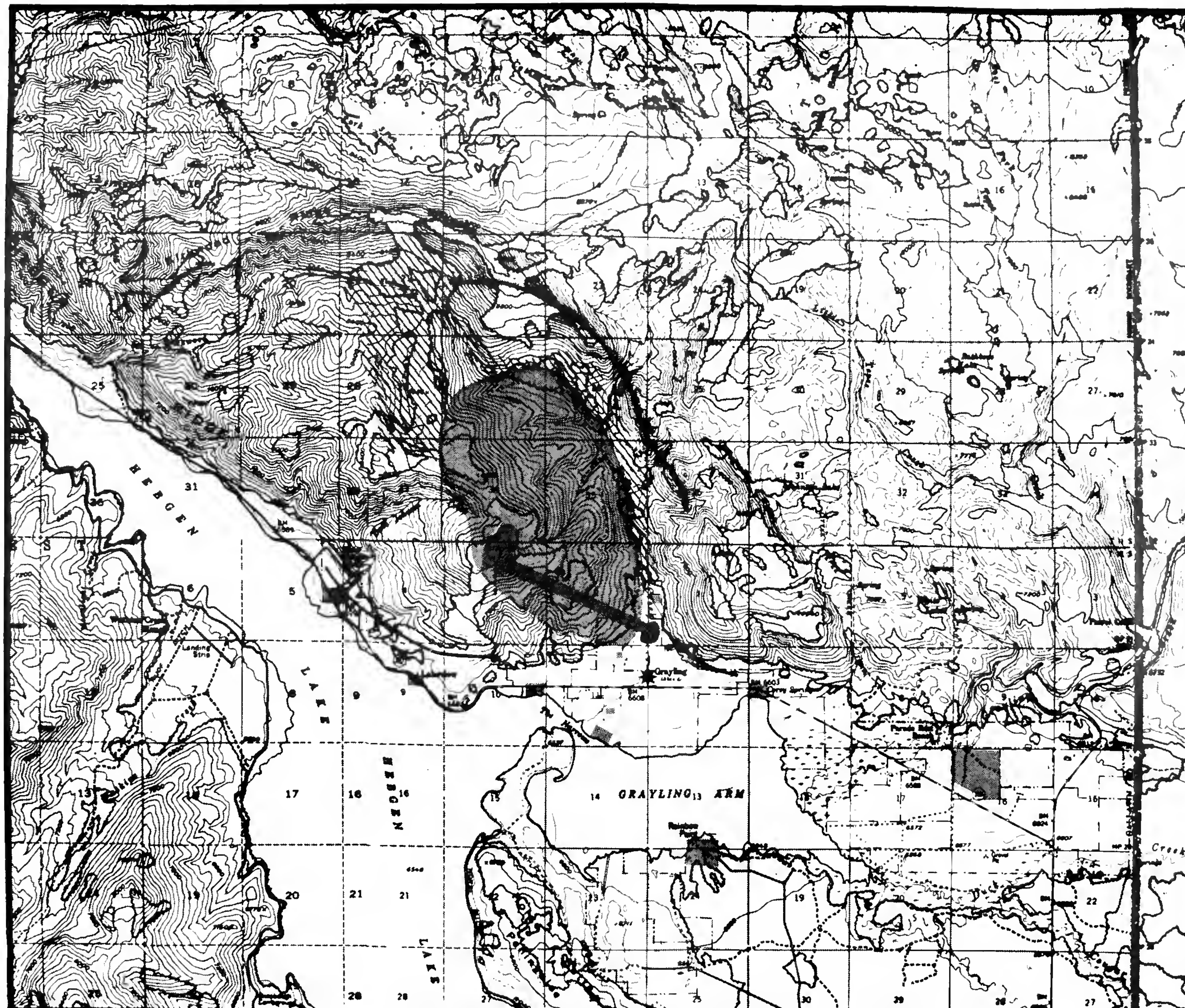

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SECONDARY STUDY AREA

RECREATION RESOURCES

FUTURE RECREATION
-- PREDICTION

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SKI YELLOWSTONE INC.
WEST YELLOWSTONE, MONTANA

SCALE 1:62500

0 5000 10,000 FEET

0 1 2 MILES

V. Socio-Economic Components

V. Socio-Economic Components

MARKET ANALYSIS
Destination Resort Corporation

INTRODUCTION

In analyzing the potential market for Ski Yellowstone, it is the position of Destination Resort Corporation (DRC) that the development must be oriented to both the winter and summer markets in order to be viable. This position is based on several considerations, including the following:

1. In the opinion of DRC, the quality of skiing available at Hebgen Mountain is not comparable to nearby resorts such as Sun Valley, and Jackson Hole.

2. West Yellowstone is both remote in terms of access and several hundred miles from any major metropolitan population center. This remoteness and lack of a substantial local population base negatively effect its viability as a winter resort.

3. Ski Yellowstone will be located in close proximity, 8 miles, to Yellowstone National Park which attracts more than two million visitors during the summer. This proximity puts the proposed development in an excellent position to attract a portion of this market.

4. Ski Yellowstone will be located on property which adjoins Hebgen Lake, thus providing a variety of recreational amenities which could be effectively utilized in attracting summer visitors.

Two separate approaches were used in analyzing these market potentials. The first approach was the traditional demand analysis, involving statistical projections of skier days and summer visitors. The second approach was to evaluate the development's potential on the basis of supply, that is, Ski Yellowstones' capability to accommodate visitors in terms of recreation and lodging capacity.

DEMAND ANALYSIS, WINTER MARKET

The 1960's saw tremendous growth in the national skier market. This expansion can be attributed to four factors: (1) a rapid increase in household income so that more people could afford to ski; (2) the rise in leisure time, not from a shorter work week (the average person only worked 50 hours less per year in 1970 than in 1960) but from more holidays and longer vacations; (3) the rapid development of new ski areas close to population centers; (4) improved air travel and highway networks significantly decreasing travel time to ski resorts.

In the 1960-1961 ski season, an estimated 1.15 percent of the United States population (179 million), or 2.1 million people, skied an average of 10.27 days, generating an estimated skier day count of 21.3 million. To project these figures to the 1970-1971 and 1980-1981 seasons, the income distribution of skiers in 1960 was evaluated and then projected for 1970 and 1980. Then the number of skiers and resulting skier-days from each income group were estimated. This analysis for the 1970-1971 and 1980-1981 ski season is indicated in Table 1. As shown, it is estimated that in 1970-1971 there were 4.1 million skiers in the United States. On the basis of an estimated average 16 days skied per skier,

TABLE 1
PROJECTED GROWTH IN THE NATIONAL
SKIER MARKET
1970-71 and 1980-81 1/

Income Group 1970-1971	Percentage of Population	Population (thousands)	Number of Skiers	Percentage of Skier Participants	Skiers per 1000 Population
Less than $4,000	23%	46,733	162,600	4%	3.5
$4,000-$6,499	21	42,669	325,100	8	7.6
$6,500-$9,999	28	56,892	894,100	22	15.7
$10,000-$14,999	19	38,605	1,341,100	33	34.7
$15,000-$24,999	6	12,191	812,800	20	66.7
$25,000 and more	3	6,095	528,300	13	86.7
Total or Average	100%	203,185	4,064,000	100%	20.0
1980-1981					
Less than $4,000	10%	22,721	56,800	1%	2.5
$4,000-$6,499	10	22,721	113,600	2	5.0
$6,500-$9,999	16	36,354	397,600	7	10.9
$10,000-$14,999	27	61,347	1,363,200	24	22.2
$15,000-$24,999	28	63,620	2,669,600	47	42.0
$25,000 and more	9	20,450	1,079,200	19	52.8
Total or Average	100%	227,213	5,680,000	100%	25.0
Average Annual Growth Rate		1.1%	3.4%		2.3%

1/ Constant 1970 Dollars

SOURCE: ERA

67.4 million skier-days were generated.

Also shown in Table 1 are comparable data for the 1980-1981 ski season. It is projected that in 1980-1981, 5.7 million people will ski for an average of 19 days per skier, generating total skier days of 116.2 million. It is projected that 2.5 percent of the population will ski in 1980-1981 as opposed to 2.0 percent in 1970 and 1.15 percent in 1960.

Using the projections of national skier days discussed above as a basis, and taking into consideration several factors, the number of skier days Ski Yellowstone could reasonably attract was estimated. This estimate is shown in Table 2 and indicates a level of skier days ranging from 60,000 in 1974-1975 to 405,000 in 1984-1985. The factors considered in this estimate were the following:

1. The snowfall pattern at Hebgen Mountain will easily permit a skiing season of 144 days, commencing at Thanksgiving and ending at Easter.

2. Ski Yellowstone will be heavily dependent on destination or vacation skiers rather than day skiers because of its lack of a nearby large metropolitan market to draw from and its difficult accessibility. In this respect, the proposed development is very comparable to Sun Valley and Jackson Hole.

3. Accessibility to Ski Yellowstone would be improved by winter operation of the West Yellowstone airport. But the effect would be limited. Analysis of the winter operation of the Jackson Hole airport revealed less than 10 percent of persons skiing at Jackson Hole travelled by air through the Jackson Hole airport. Because of the snow removal and weather problems at West Yellowstone airport, no consideration was given to the potential benefit of winter operation of its facilities.

4. The recent experience of Grand Targhee was used as a partial basis for determining what level of skier days Ski Yellowstone could reasonably attract in its initial years of operation. Although Grand Targhee is more oriented to day skiers, it opened in the same market area with comparable facilities to those proposed for Ski Yellowstone's initial development, In its initial year of operation, 1970-1971, Grand Targhee experienced approximately 72,000 skier days. During the 1972-1973 season, an estimated 120,000 skier days were recorded. Data on Grand Targhee and other resorts is shown in Table 1.

5. The growth rate used in estimating skier days at Ski Yellowstone was developed from DRC file data on other winter resorts which are resort or vacation oriented and have been well operated and promoted. These resorts included Aspen, Snowmass, Vail and Sun Valley.

DEMAND ANALYSIS, SUMMER MARKET

Typically, market support for a resort complex such as envisioned at Ski Yellowstone is derived from two basic sources: The resident and tourist markets. However, in the case of West Yellowstone, which is remotely located from any

TABLE 2

PROJECTED SKIER DAYS
AND TOTAL WINTER VISITOR DAYS AT SKI YELLOWSTONE

SKI SEASON	PROJECTED SKIER DAYS	TOTAL WINTER VISITOR DAYS 1/
1974-1975	60,000	72,000
1975-1976	80,000	96,000
1976-1977	110,000	133,000
1977-1978	150,000	183,000
1978-1979	190,000	232,000
1979-1980	230,000	283,000
1980-1981	265,000	326,000
1981-1982	305,000	378,000
1982-1983	335,000	415,000
1983-1984	370,000	463,000
1984-1985	405,000	505,000

1/ Projected skier days plus 20 percent non-skiers in 1974-1975 increasing to 25 percent non-skiers in 1984-1985.

SOURCE: DRC

significant resident population, primary market potential will be generated by tourists already visiting the area, or attracted by the new development. The validity of this conclusion is easily demonstrated through the analysis of traffic flows in the vicinity of West Yellowstone. During the months of May through October, at which time all entrances to Yellowstone National Park are open, 90 to 95 percent of highway travelers visiting the park reside more than one half to one day's drive from the area. Thus, most visitors to the area are recreation-oriented and, because of the long distances they have driven, represent demand for overnight accommodations.

In Table 3, attendance to the park, by place of entrance and mode of travel, is shown for the 1969-1972 period. Total attendance to Yellowstone National Park increased from 2,199,532 in 1969 to 2,246,428 in 1972, for an average annual growth rate of 0.7 percent. Oversnow travel increased from 11,086 to 25,639 in 1972, representing a 35 percent average annual increase. During the 1969-1972 period, approximately 30 percent of total park visitors entered through the park's west entrance. Numbering 693,000 persons in 1972, the average annual growth rate for these visitors has been 1.4 percent.

As indicated previously, primary market support for the proposed development can be ascertained by analyzing the traffic flow on major highway arteries in the West Yellowstone area. On the basis of traffic flow distributions, about 555,000 recreation and pleasure oriented visitors passed through West Yellowstone between May and October of 1972, as shown in Table 4. Taking the average between the estimate and the number of visitors to the west entrance of Yellowstone National Park indicates summer recreation visitors in West Yellowstone amounted to approximately 610,000 in 1972.

Using the estimate of summer visitors in 1972 as a base year, and a growth rate consistent with past experience, the number of summer visitors to West Yellowstone from 1975 through 1985 has been projected. These projections are shown in Table 5 and indicate 647,000 in 1975, increasing to 789,000 in 1985.

SUPPLY ANALYSIS, WINTER VISITORS

The second approach used in analyzing the potential market for Ski Yellowstone is based on the recognition that the success of a ski resort is as dependent upon its ability to accommodate visitors, both in terms of skier capacity and sleeping capacity, as it is upon market demand for such resorts. Given the magnitude of the projected national skier market shown in Table 1, there is no question in our opinion that adequate demand exists for properly promoted and operated ski resorts. Consequently, it is important to determine if the proposed Ski Yellowstone development can accommodate projected winter visitors.

Using the projected skier days and total visitors indicated in Table 2, the skier capacity of Hebgen Mountain and sleeping capacity required to accommodate these visitors was calculated. These calculations are shown in Table 6 and indicate for the 1984-1985 season a skier capacity of 6,000 per day and a sleeping capacity of 5,915 per night will be required. Based on our understanding of the developable skier capacity of Hebgen Mountain and the housing capacity of

TABLE 3

VISITORS TO YELLOWSTONE NATIONAL PARK
BY PLACE OF ENTRANCE AND MODE OF TRAVEL
1969-1972

Place of Entrance and Mode of Travel	1969 Number	1969 Percentage	1970 Number	1970 Percentage	1971 Number	1971 Percentage	1972 Number	1972 Percentage	Average Annual Increase (Decrease) 1969-1972
West - Oversnow	8,928	80.5%	12,687	77.0%	16,707	81.0%	21,873	85.3%	35.0%
West - Cars and Buses	656,807	30.0	677,072	29.7	609,216	29.0	671,028	30.2	0.8
West - Total	665,735	30.3%	689,759	30.0%	625,923	29.5%	692,901	30.8%	1.4%
East - Oversnow	731	6.6%	1,394	8.5%	647	3.1%	474	1.8%	(1.8)%
East - Cars and Buses	513,597	23.4	529,064	23.2	466,349	22.2	479,325	21.6	(2.4)
East - Total	514,328	23.4%	530,458	23.1%	466,996	22.0%	479,799	21.4%	(2.4)%
North - Oversnow	1,175	10.6%	1,968	11.9%	1,250	6.1%	818	3.2%	(12.8)%
North - Cars and Buses	255,988	11.7	264,467	11.6	258,980	12.3	274,464	12.4	2.4
North - Total	257,163	11.7%	266,435	11.6%	260,230	12.3%	275,282	12.3%	2.3%
Northeast - Oversnow	0	0	0	0	0	0	0	0	0
Northeast - Cars and Buses	110,188	5.0%	106,345	4.7%	112,108	5.3%	114,737	5.2%	1.4%
Northeast Total	110,188	5.0%	106,345	4.6%	112,108	5.3%	114,737	5.1%	1.4%
South - Oversnow	252	2.3%	434	2.6%	2,018	9.8%	2,474	9.7%	122.0%
South - Cars and Buses	651,866	29.6	703,672	30.8	653,019	31.1	681,235	30.6	1.5
South - Total	652,118	29.6%	704,106	30.7%	655,037	30.9%	683,709	30.4%	1.6%
Total - Oversnow	11,086	100.0%	16,483	100.0%	20,622	100.0%	25,639	100.0%	32.0%
Total - Cars and Buses	2,188,446	100.0%	2,280,619	100.0%	2,099,672	100.0%	2,220,789	100.0%	0.7%
Total - Total	2,199,532	100.0%	2 297,102	100.0%	2,120,294	100.0%	2,246,428	100.0%	0.7%

SOURCE: U.S. Department of the Interior, Yellowstone National Park

TABLE 4

ANALYSIS OF RECREATION VISITORS
IN THE WEST YELLOWSTONE AREA
1972

	5. MILES WEST OF W. Y.		7.7 MILES NORTH OF W. Y.
Total Persons in 1972 (Average Daily Traffic x 2.4 persons per car)	1,122,000		1,052,000
Estimated Number of Recreation Visitors (60 percent of total)	673,000		631,000
Average for May - October		554,000	
Visitors to Yellowstone Park (West Entrance)		671,000	
Summer Recreation Visitors in West Yellowstone		610,000 1/	

1/ Average of estimated number of recreation visitors and visitors to the West entrance of Yellowstone park.

Source: Montana Department of Highways, Yellowstone National Park, and DRC

TABLE 5

PROJECTED SUMMER VISITORS TO WEST YELLOWSTONE

SUMMER	PROJECTED VISITORS TO WEST YELLOWSTONE
1975	647,000
1976	660,000
1977	673,000
1978	687,000
1979	701,000
1980	715,000
1981	729,000
1982	744,000
1983	758,000
1984	774,000
1985	789,000

SOURCE: DRC

TABLE 6

WINTER VISITOR DAYS AND SLEEPING CAPACITY AND SKIER CAPACITY REQUIRED AT SKI YELLOWSTONE

Ski Season	Projected Skier Days	Visitor Days Total 1/	Visitor Days Day 2/	Visitor Days Overnight	Sleeping Capacity Required 3/	Skier Capacity Required
1975-1976	60,000	72,000	22,000	50,000	800	1200
1976-1977	80,000	96,000	29,000	67,000	1070	1600
1977-1978	110,000	133,000	35,000	98,000	1570	2090
1978-1979	150,000	183,000	40,000	143,000	2145	2850
1979-1980	190,000	232,000	42,000	190,000	2850	3420
1980-1981	230,000	283,000	44,000	239,000	3585	4140
1981-1982	265,000	326,000	46,000	280,000	3920	4505
1982-1983	305,000	378,000	47,000	331,000	4635	5185
1983-1984	335,000	415,000	48,000	367,000	5140	5360
1984-1985	370,000	463,000	49,000	414,000	5380	5550
1985-1986	405,000	505,000	50,000	455,000	5915	6000

1/ Projected skier days plus 20 percent non-skiers in 1974-1975 increasing to 25 percent non-skiers in 1984-1985.
2/ 30 percent of total visitor days in 1974-1975 decreasing to 10 percent in 1984-1985.
3/ 1.6 percent of overnight visitor days in 1974-1975 decreasing to 1.3 percent in 1984.1985.
4/ 2.0 percent of skier days in 1974-1975 decreasing to 1.5 percent in 1984-1985.

Source: DRC

the proposed site, it is the opinion of DRC that the requirements set forth in Table 6 can comfortably be accommodated. It should be noted, as will be discussed later, that a small portion of the required sleeping capacity will be accommodated by the existing inventory of beds in West Yellowstone, thus enhancing the proposed sites ability to supply sleeping capacity.

SUPPLY ANALYSIS, SUMMER VISITORS

Considering the seasonal pattern of summer visitors to West Yellowstone, the supply of accommodations required to satisfy the winter market will be more than adequate to accommodate summer visitors.

ECONOMIC IMPACT OF THE PROPOSED DEVELOPMENT

Destination Resort Corporation

INTRODUCTION

Analysis of the economic impact of the proposed development indicates it will be a significantly positive one as measured in terms of providing full time employment, balancing the economics of both West Yellowstone and Gallatin County, and providing for more efficient use of the resources of the region. The analysis consisted of three basic steps; (1) a thorough evaluation of the economics of West Yellowstone and Gallatin County, (2) an analytical determination of the income multiplier to be applied to the projected earnings of employees and proprietors of the proposed development, and (3) a general analysis of selected areas where the proposed development will have an economic impact. Each of these three steps will be discussed in the following paragraphs.

LOCAL AND REGIONAL ECONOMICS

The economics of West Yellowstone and Gallatin County are remarkedly different in their makeup, yet share a common problem of imbalance and vulnerability.

WEST YELLOWSTONE

West Yellowstone has long been a summer stop-over point for tourists visiting Yellowstone National Park. The dependence of West Yellowstone's economy on these tourists is clearly evidenced by the substantial inventory of motel rooms, approximately 3,000 rooms, and the seasonality of business activity, from June to September, which reflects the pattern of tourists visiting Yellowstone National Park. The dependence of West Yellowstone on a large volume of very seasonal tourists leaves it vulnerable to fluctuations in the volume of these tourists, such as occurred during the 1973 summer season.[1] More importantly, the majority of motels and retail businesses in West Yellowstone are closed for approximately eight months a year which results in a very inefficient use of these resources.

The economy of West Yellowstone could be meaningfully aided by winter business activity. Given the nature of its resources, this activity would have to come from winter tourism. The increasing tourism to Yellowstone National Park in the winter, particularly snowmobiles, is having a noticeable effect on West Yellowstone economy. A substantially larger impact, however, is needed to balance the large volume of summer tourism.

GALLATIN COUNTY

The economy of Gallatin County is dominated by the City of Bozeman, whose economy is in turn dominated by the State University. The influence of Montana State University on the Gallatin economy is substantial, as evidenced by the fact that nearly 20 percent of the county's total personal income in 1970 came from State and local government employment, compared to 9.5 percent for the State of Montana. The heavy dependence of Gallatin's economy on primarily state employment represents an imbalance which is reflected in other sections of the economy, such as lower farm and private nonfarm employment. In addition, the

1 Tourism in West Yellowstone decreased an estimated 7 percent during the 1973 summer season.

five year trend from 1966 to 1970 indicates this dependence is increasing slowly at an average annual rate of 1 percent per year, as shown in Table 1.

This imbalance in the economy of Gallatin County is not serious now, nor will it be in the foreseeable future. However, should the State University system decide to limit the growth potential of the Bozeman campus, other sections of the county's economy would have to provide additional employment, assuming population continues to grow at the moderate rate of 2.5 percent per year.

In summary, the economics of West Yellowstone and Gallatin County have an imbalance which leaves them vulnerable. West Yellowstone is heavily dependent on summer tourism while Gallatin County is heavily dependent on employment related to Montana State University. Both economies would be strengthened by a major winter tourist attraction such as Ski Yellowstone. The validity of this statement is discussed in the following sections of the report.

INCOME MULTIPLIER

A common analytical approach used in making plans for improving the economic health of an area is to use the personal income structure of the area as a framework for (1) assessing the strengths and weaknesses of the economy, (2) detecting deficiences in the area's current economy, and (3) gauging the economic impact of a new or expanded type of economic activity. Before discussing these uses, however, a brief explanation of three basic concepts is necessary. These include (1) a description of the way in which a region grows economically, (2) the nature and determination of the location quotient, and (3) measurement of the income multiplier.

EXPORT-BASE THEORY

A widely accepted, and pragmatically useful, theory of regional economic growth is the export-base theory. It holds that in any area the level of total economic activity is determined by the activity in those industries which are producing for export outside of their area. It is these export industries that provide the major impetus for an area's economic growth or decline.

The export-base theory classifies each industry in an area as being export or residentiary. Export, or basic, industries are those in which an area specializes and in which it produces more than it needs. This excess is sent to other areas and the income received from it is used to pay for imports. Area specialization in basic industries occurs for one or two reasons. The presence of mineral deposits, arable land, desirable climate, or some other natural advantage may dictate the development of a particular industry in a given area. Second, certain industries can lower costs significantly through economies of scale. In most instances, however, to take full advantage of economies of scale, it is necessary to produce a much larger quantity than that required locally. It is obvious, for example, if an area produced only the automobiles needed in its local market, assembly lines and mass production techniques would be uneconomical and perhaps unknown, and automobile costs would be several times higher than they are.

TABLE 1

PERSONAL INCOME BY MAJOR SOURCES
AND EARNINGS BY BROAD INDUSTRIAL SECTOR

(Thousands of Dollars)

	1966	1967	1968	1969	1970
Total personal income	67,407	71,983	77,788	82,796	91,663
Total wage and salary disbursements	41,113	43,526	46,852	50,098	56,507
Other labor income	1,389	1,450	1,580	1,765	2,068
Proprietors income	11,625	11,425	11,805	12,442	12,540
Farm proprietors income	4,873	3,999	4,246	4,937	4,890
Nonfarm proprietors income	6,752	7,426	7,559	7,505	7,650
Property income	9,953	11,565	12,785	13,519	14,611
Transfer payments	5,637	6,672	7,567	8,150	9,542
Less: Personal contributions for social insurance	2,310	2,655	2,801	3,178	3,605
Total earnings	54,127	56,401	60,237	64,305	71,115
Farm earnings	5,986	5,232	5,325	6,137	6,105
Total nonfarm earnings	48,141	51,169	54,912	58,168	65,010
Government earnings	16,571	17,353	19,055	20,948	23,331
Total federal	3,968	4,162	4,487	4,618	5,322
Federal civilian	3,426	3,538	3,829	3,897	4,562
Military	542	624	658	721	760
State and local	12,603	13,191	14,568	16,330	18,009
Private nonfarm earnings	31,570	33,816	35,857	37,220	41,679
Manufacturing	5,303	5,645	5,945	6,496	6,625
Mining	135	173	176	(D)	(D)
Contract construction	3,443	3,579	3,295	3,473	4,783
Trans., communication, and public utilities	2,816	2,679	2,868	3,070	3,190
Wholesale and retail trade	9,347	9,913	10,750	10,523	11,974
Finance, insurance, and real estate	1,895	2,126	2,330	(D)	(D)
Services	8,341	9,433	10,200	10,709	11,848
Other	290	268	293	297	346

(D) not shown to avoid disclosure of data for individual reporting units. Data are included in totals.

The residentiary industries in each area are those which serve the needs of other local industries and local households. These include trade, transportation, public utilities, finance, services, and construction industries. They require no special natural resources and their potential economies of scale can be realized by production for the local market.

According to the export-base theory, an area's economic growth depends mainly upon the expansion of its basic industries. If demand for basic industry output increases, employment and earnings in these industries also will increase by the industries' current labor force being worked overtime, by unemployed workers in the area being hired, or by new workers migrating into the area from outside.

As incomes in the area expand with the increased production of basic industries, the demand for the products of residentiary industries will increase also. That is, the new plants, or the more fully utilized old plants, of the basic industries will require numerous inputs produced locally by the residentiary industries, such as banking, legal, advertising, and transportation services.

Moreover, the increased earnings of workers in both industries will generate a further increase in the demand for goods and services of residentiary industries. Employees in basic and supporting industries will demand more retail trade and transportation facilities, more financial services, entertainment, and gasoline; and more auto repair and maintenance and public education facilities. To meet these demands the residentiary industries will have to expand production and the earnings of employees will rise. The increased earnings of the newly employed workers also will be spent, in part, on the output of residentiary industries, thus adding another round to the income effects of the expansion in basic industry production. The total expansion in income which stems from an increase in a basic industry is known as the income multiplier effect. This analytical tool will be discussed later in this section.

LOCATION QUOTIENT

For the export-base theory of growth to be practical, the basic industries of an area must be identified and measured. Some industries, such as agriculture, Federal Government, and tourism can be classified as basic, or export, without difficulty. In many areas, a portion of some of these industries can be classified as residentiary because their output is purchased by local residents. This is generally so small a portion of the total, however, that it is ignored.

In general, industries other than those listed above are classified as residentiary. However, many residentiary industries are partly basic and the accuracy of the multiplier can be improved significantly if the basic activity can be disentangled from the residentiary.

A simple method of dividing a residentiary industry into its basic and residentiary portions is through the use of location quotients. A location quotient measures the relative importance of an industry in an area's economy. If the industry is of above-average importance, it is assumed to be producing more than is needed for the local market and, hence, to be exporting a portion of its

output. If the industry is of less-than-average importance, it is assumed that the deficiency is being made up by importing. If the industry is of average importance, it is assumed that all of its output is being consumed locally.

The location quotient for a given industry is calculated by computing the percentage of that industry's earnings of the total income in the area. A similar computation is made for the parent region--usually the state or the nation. The area percentage is then divided by the national percentage to produce the location quotient.

INCOME MULTIPLIER

The income multiplier is the final concept to be discussed before personal income can be used as an analytical framework. The need for the income multiplier usually arises when an area is considering the advantages or disadvantages of a particular line of economic action. It may be that a potential industry is requesting tax concessions to locate in the area; or, that a prospective industry is known to have adverse side effects (i.e. excessive pollution); or, that another industry requires that the local government make a substantial outlay to develop needed facilities. Knowledge of the potential economic contribution of the industry to the local economy would be useful in arriving at a policy decision regarding the benefits versus the costs of the new industry.

A direct measure of the monetary benefits can be established by applying the income multiplier to the estimated earnings of employees of the potential industry. This will yield an estimate of the impact of the industry on total income in the area.

To determine the income multiplier, the procedure outlined above was used. The income multiplier for Gallatin County only was calculated, as the necessary data for West Yellowstone is not publicly available. Applying derived location quotients to each sector of the Gallatin economy, an income multiplier of 3.07 was calculated, as shown in Table 2. This is an exceptionally high multiplier and indicates that for every dollar paid out in earnings (wages and salaries and proprietary income) by Ski Yellowstone, residentiary or local earnings will increase by $2.07. A high income multiplier is typically associated with tourist operations, particularly when the majority of tourists reside outside the local area. Ski Yellowstone will attract virtually all of its tourists from outside Gallatin County, thus the high income multiplier is warranted.

ECONOMIC IMPACT

The economic impact of Ski Yellowstone will be wide ranging and affect several areas including employment, housing, schools, retail sales, government services, and local, state, and federal taxes. Each of these areas will be discussed in the section of the report. As indicated previously in this report, the proposed Ski Yellowstone development will consist of both a winter and summer operation, as well as a major real estate program. All planning and financial aspects of the real estate program have not been finalized as of the writing of this report, thus the full economic impact of this part of the development cannot be assessed at this time. As soon as the real estate program is established, its economic

TABLE 2
COMPUTATION OF INCOME MULTIPLIER
(Thousands of Dollars)

Total Personal Income	$91,663
<u>Basic Earnings</u>	29,853
Farm	6,105
Federal Government	5,322
State Government	9,328
Manufacturing	6,625
Services	2,473
Multiplier	3.07

TABLE 3
PROJECTED DIRECT AND INDIRECT
INCOME RESULTING FROM THE
PROPOSED SKI YELLOWSTONE DEVELOPMENT

Year	Ski Yellowstone - Direct Income			Total Indirect Income	Total Direct and Indirect Income
	Wages & Salaries	Proprietary	Total		
1975/76	$ 289,000	$ 311,000	$ 600,000	$1,242,000	$1,842,000
1976/77	330,500	459,500	789,500	1,634,500	2,424,000
1977/78	371,000	680,000	1,051,000	2,175,500	3,226,500
1978/79	433,500	922,500	1,356,000	2,807,000	4,163,000
1979/80	497,500	1,179,500	1,677,000	3,471,500	5,148,500
1980/81	560,000	1,378,500	1,938,500	4,012,500	5,951,000
1981/82	635,000	1,662,000	2,297,000	4,755,000	7,052,000
1982/83	707,500	1,905,500	2,613,000	5,409,000	8,022,000
1983/84	755,000	2,154,000	2,909,000	6,021,500	8,930,500
1984/85	820,000	2,322,500	3,142,500	6,505,000	9,647,500

impact will be determined and a report submitted.

INCOME

The most significant impact of Ski Yellowstone will be in the area of income, both proprietary and wages and salaries. Using the projections of visitor expenditures and operating expenses shown in the Ski Yellowstone marketing and feasibility report prepared by Destination Resort Corporation, total direct income or earnings generated by Ski Yellowstone will amount to $600,000 in 1975/1976, increasing to $3,142,500 by 1984/1985. Direct wages and salaries of persons connected with Ski Yellowstone are projected to total $289,000 in 1975/1976 and $820,000 in 1984/1985. Income from proprietary operations directly supported by projected expenditures of visitors to Ski Yellowstone is estimated to total $311,000 in 1975/1976 and increase to $2,322,500 by 1984/1985. These figures are shown in Table 3.

Indirect earnings which can be attributed to Ski Yellowstone, using the income multiplier previously discussed, are projected to total $1,242,000 in 1975/1976 and $6,505,000 in 1984/1985. These earnings will be realized by businesses and proprietors providing goods and services to Ski Yellowstone and its visitors. Projections of indirect earnings for each year from 1975/1976 to 1984/1985 are shown in Table 3.

Total income or earnings resulting from the development of Ski Yellowstone, both direct and indirect, is projected to amount to $1,842,000 in 1975/1976 and increase to $9,647,500 by 1984/1985. The magnitude of these projections can be gauged by comparing them to total income for Gallatin County in 1970. In 1975/1976, projected income will amount to 2 percent of total county income in 1970. By 1984/1985, this percentage would increase to 10.5 percent. Of course, Gallatin County's income will have increased by those years, thus the percentage would not be as large.

EMPLOYMENT

Total employment directly associated with the operation of Ski Yellowstone is estimated to amount to 265 persons in 1975/1976, increasing to 654 by 1982/1983. Of this total, full time employees will account for 130 in 1975/1976 and 279 in 1982/1983. A schedule of projected employment is shown in the following text table.

PROJECTED DIRECT EMPLOYMENT

Phase	1975/76 I	1978/79 II	1980/81 III	1982/83 IV
Ski Yellowstone 1/				
Full Time	75	107	136	159
Part Time	55	85	115	155
Subtotal	130	192	251	314
Proprietary 2/				
Full Time	55	75	100	120
Part Time	80	120	180	220
Subtotal	135	195	280	340
Total				
Full Time	130	182	236	279
Part Time	135	205	295	375
Total	265	387	531	654

1/ Operating and Overhead staff.

2/ Proprietors of shops, motels, and restaurants which are part of the Ski Yellowstone development.

HOUSING

The impact on housing of Ski Yellowstone is somewhat difficult to evaluate because of the unknown family relationships of persons to be employed by Ski Yellowstone and the undetermined nature of the proposed real estate program. It is probable most persons working full time at Ski Yellowstone will either purchase one of the available condominiums or build on one of the single family lots. Part time employees will be accommodated in either proposed employee housing to be constructed by Ski Yellowstone or in West Yellowstone. In summary, the majority of the housing impact will be realized on the site itself, with modest impact on West Yellowstone.

SCHOOL

The existing school system in West Yellowstone presently accommodates approximately 250 students, but is capable of double the number, or 500 students. It is estimated that by 1980, the capacity of the existing school system will be exceeded by the impact of Ski Yellowstone. It is difficult to estimate the number of children because of the number of persons related to indirect earnings and employment. To the extent existing businesses can absorb this impact, the number of families will not increase significantly, and thus have little impact on the school system.

RETAIL SALES

Retail sales have been projected in the Destination Resort Corporation working report and are estimated to total $2,075,000 in 1975/1976 and increase to $15,484,000 by 1984/1985. These sales include lodging, restaurants, shops, and entertainment.

GOVERNMENT SERVICES

Ski Yellowstone will not require a high level of government services due to its self contained nature. The development will install and operate its own water and sewage systems. Roads will also be constructed by Ski Yellowstone and maintained by them or possibly Gallatin County or the state. The Gallatin County government will be expected to provide services consistent with the tax revenues the development generates.

TAXES

It is projected Ski Yellowstone will generate substantial tax dollars for all levels of government. Locally, the Gallatin County property tax will amount to approximately $130,000 annually at the present tax rate and based on capital improvements amounting $8,150,000. The real estate program will significantly increase this amount, perhaps by two or three times when complete.

The State and Federal governments will derive income tax from all persons employed by Ski Yellowstone, as well as the development itself. The proforma financial analysis for Ski Yellowstone shown in Destination Resort Corporation's marketing and feasibility study indicates the project will pay a fee to the U.S. Forest Service amounting to $20,500 in 1975/1976, increasing to $113,000 in 1984/1985. No federal or state income tax is projected to be paid in the initial years of operation due to the depreciation of the capital investment.

LAND USE ASPECTS
Beardsley, Davis Associates, Inc.

LAND USE

Land in the vicinity of the proposed Ski Yellowstone development site is primarily public land, managed by the U.S. Forest Service. The 211,200-acre Hebgen Lake District contains about 10,860 acres of privately-owned land. Approximately 250 acres, or 5%, comprise the town of West Yellowstone. The large percentage of public land to a great extent determines the land use of the major portion of the Hebgen Lake area. The Ski Yellowstone site is within the Madison River Canyon Earthquake Area of the Gallatin National Forest. The forest in this area is managed with an emphasis on recreation, focusing on the geologic phenomena associated with the 1959 earthquake. Small amounts of timber cutting have taken place in some portions of this area, but for the most part the public land remains in a fairly natural state. Private land, excluding the town of West Yellowstone, has begun to be subdivided (Figure 1 and Table 1) and recreation homes are being built. Some small summer resort developments are located near Hebgen Lake, with most being comprised of cabins or lodges and a few having marina facilities. Also, several small trailer or recreation vehicle parks are located in this area.

The town of West Yellowstone has, according to the 1970 U.S. Census, a permanent year-round population of 756. The permanent summer population is estimated to be around 2000. Tourist beds available in summer number 3500; in winter, 1500. The town contains 71 motels, 25 restaurants, and 14 gas stations. Housing for permanent residents consists primarily of house trailers and converted summer houses. Located approximately one mile northwest of the West Yellowstone townsite is the Yellowstone Airport, which occupies 790 acres. Several highways (U.S. 287, U.S. 191, and U.S. 20) and many unimproved dirt and light-duty roads pass through the Hebgen Lake area.

At the present time there are no county-wide regulations existing in Gallatin County, no county zoning standards and, no master planning exists for the town of West Yellowstone. The only development controls present are in the form of Senate Bill 208, the State and County Health Departments, and the County Commissioners through the City-County Planning Board. A new subdivision ordinance is in the process of being formulated, and should be effective within two or three months. An interim subdivision ordinance is forthcoming in the near future. In the meantime, the State of Montana's policy of non-degradation of existing high water quality, however, may well serve as the most effective growth control. Certainly with the increase in recreational pressures in this area, it will be increasingly important to develop and adopt land use controls to more effectively guide new development.

For the "West Yellowstone Division" (U.S. Census) of Gallatin County, which includes the region extending from the south and east borders of the state to fifty miles north of West Yellowstone and fifteen miles west of West Yellowstone, the 1960 population was 599 and the 1970 population was 1,099.

TABLE 1

SUBDIVISION LOCATED IN WEST YELLOWSTONE AREA

Name of Subdivision	Location	Number of Lots	Average Size of Lots	Total Acres	Number of Lots Developed	Number of Lots Undeveloped	Number of Lots Sold to Private Parties	Number of Lots Held by Developer	Type of Subdivision	Date Recorded
1	2	3	4	5	6	7	8	8	10	11
BEAR TRAP RANCH 7	Co.	26	4.2 ac.	20.1	7	19	14	12	Recreational	12-10-70
BEAR TRAP RANCH NO. 2 8	Co.	56	2 ac.	182.7	3	53	15	41	Recreational	12-09-71
BUCKLEY TRACT 15	Co.	2	1.3 ac.	2.6	0	2	0	2	Private Res.	11-27-72
HEBGEN LAKE NO 1 25	Co.	35	180'x210'	38.2	7	28	6	29	Recreational	5-03-66
HEBGEN LAKE NO 2 26	Co.	50	220'x200'	58.5	0	50	3	47	Recreational	5-23-66
HORSE BUTTE 29	Co.	19	1 ac.	26	0	19	3	16	Recreational	9-15-70
KIRKWOOD RIDGE MEADOWS 34	Co.	30	10,000 sq. ft.	9.8	9	21	23	7	Recreational	11-06-67
RANCHO VISTA CABIN SITES 50	Co.	14	200'x136'	7.8	2	12	14	0	Recreational	10-11-66
YELLOWSTONE HOLIDAY NO. 1 69	Co.	63	.5 ac.	30.3	9	54	54	9	Recreational	1-06-66
YELLOWSTONE HOLIDAY NO. 2 70	Co.	6	80'x36'	.75 ac.	6	0	6	0	Recreational	12-05-66
YELLOWSTONE HOLIDAY NO. 3 71	Co.	137	15,400 sq. ft.	68.9	0	137	1	137	Recreational	2-11-70
PROPOSED KIRKWOOD MEADOWN 35	Co.	32	.25 to 5	15.5					Recreational	
PROPOSED HEBGEN LAKE ESTATES 30	Co.	149	.25 to 1	77 - 20 lots of the 149 are for Mobile Homes					Recreational	

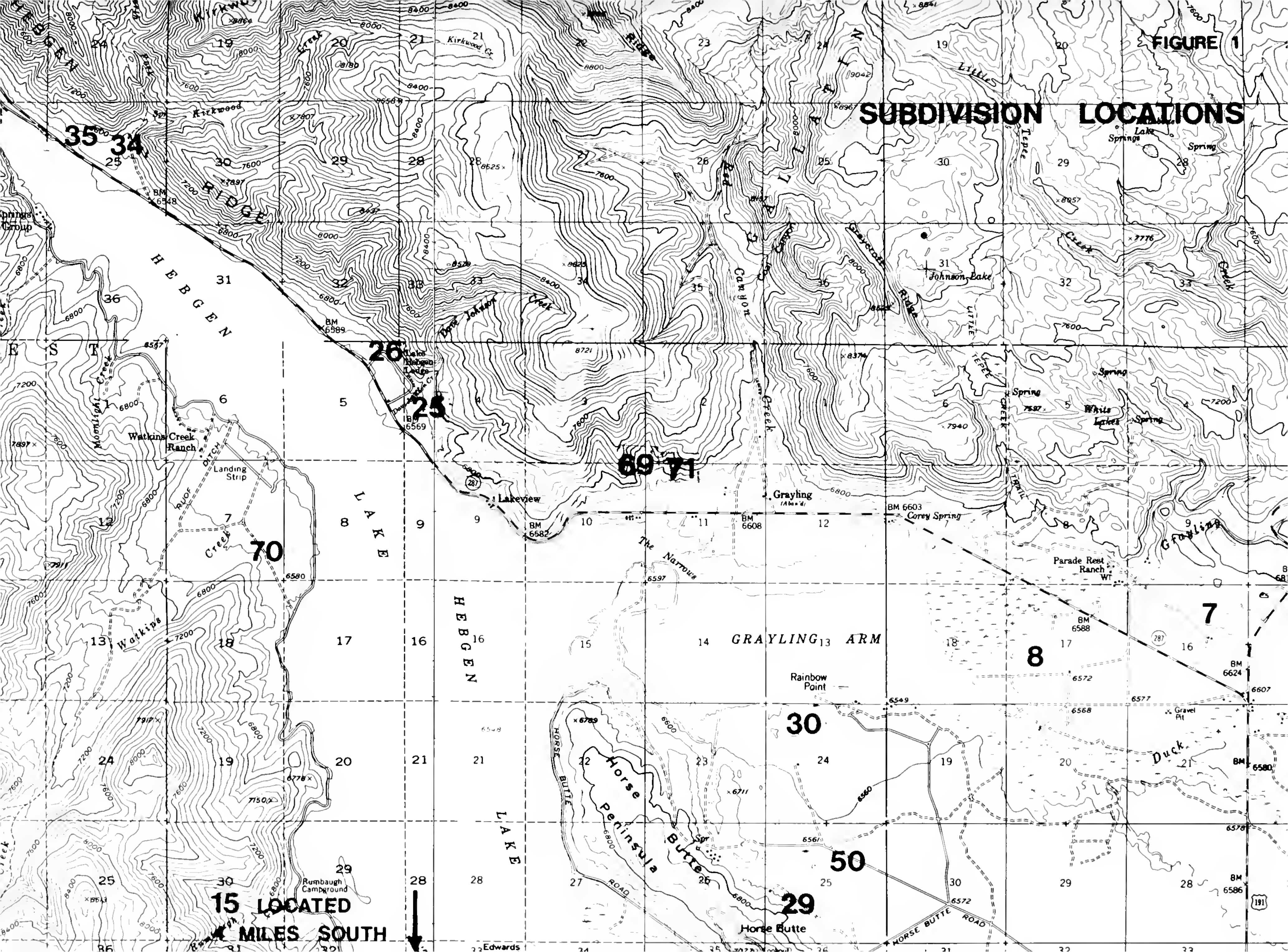
FIGURE 1
SUBDIVISION LOCATIONS
15 LOCATED 4 MILES SOUTH
HEBGEN LAKE
GRAYLING ARM
Horse Butte Peninsula
Horse Butte
Rainbow Point
Lakeview
Grayling
Parade Rest Ranch
Watkins Creek Ranch
Landing Strip
Rumbaugh Campground
Kirkwood Ridge
Red Canyon
Johnson Lake
Corey Spring
The Narrows
Lake Hebgen Lodge
35
34
26
25
69
71
70
30
50
29
8
7

A forecast of "most likely population" for the county census division is given by T.A.P. Inc. of Bozeman, Montana, for 1980 as 1,343, and for 1990 as 1,674. The area thus is predicted to experience a 20-25% increase each ten years.

The proposed Ski Yellowstone development would directly alter land use characteristics of Forest Service land on Mt. Hebgen, as well as private land extending from the base of the mountain to the shore of Hebgen Lake. The Forest Service has indicated that the proposed ski trail use of Mt. Hebgen slopes will not interfere, however, with the aims of their Multiple Use Charter for this area. Since no fault scarps exist on Mt. Hebgen in the proposed development area, change to skiing recreational use would not conflict with the primary recreation emphasis at this time, which focuses on appreciation of the geologic phenomena present resulting from the Madison River Earthquake. The presence of the ski area will alter the timber cutting use of Red Canyon as it has occurred in the past, however, timber can be harvested in a manner compatible with ski trail clearing by such means as utilizing methods of selective cutting, or perhaps by doing some clear cutting where ski runs are of major significance. The present hunting access use of Red Canyon, and backpacking use of the higher country area, will not be significantly altered by the proposed ski development, however snowmobiling use within the area would be restricted to slope maintenance operations only.

Indirect effects of the proposed ski development on land use characteristics could include the type of parasitic development which is often seen to occur in the vicinity of ski areas. To prevent this problem from occurring around Ski Yellowstone, cooperation between the Forest Service, state government, and county government definitely needs to be encouraged in order that controls and regulations which do not now exist, may be formulated and enforced. Although the State of Montana's legislation regarding non-degradation of water quality will be an increasingly effective means to limit unwise growth, it alone will not be effective as a tool in positively directing desired growth.

TRANSPORTATION

The Ski Yellowstone development area is located on U.S. 287, a two-lane State highway. The town of West Yellowstone, 12 miles from the site, is reached via this road and U.S. 191. U.S. 20 passes through West Yellowstone and provides access to Yellowstone National Park and Targhee Pass area. A link to the rest of the country is provided by the Yellowstone Airport, located a mile northwest of West Yellowstone. The Union Pacific Railroad provides limited freight service to the town.

Roads in this area have all been reconstructed since the 1959 Madison River Earthquake, and no major highway improvements are anticipated by the State Highway Department during the next five years in the West Yellowstone - Mt. Hebgen area. The developers of Ski Yellowstone plan to conduct road maintenance and snow removal operations using their own equipment and labor force, at least until a possible time in the future when, and if, the county is able to assume this responsibility. U. S. 287 is currently maintained and kept open

throughout the winter by the Department of Highways with the possible exception of a few days of severe blizzard conditions.

Winter traffic volumes on highways in the area average from 40% to 60% of the average daily traffic for the year, therefore, the Montana State Department of Highways does not expect that the presence of a winter resort would lead to any highway capacity problems during the winter months. They estimate that even if a winter resort area were opened, the peak load on the highways would still occur during the summer months, when a July weekend day averages 2,850 cars traveling through the area to or from the Yellowstone Park region. An increase in traffic in the "Gallatin County Corridor", which might occur due to travel between the new ski area and the existing Big Sky area, is not foreseen by the Highway Department to cause traffic problems, as the corridor is reportedly designed to handle five times the volume of traffic it currently experiences.

The Yellowstone Airport presently operates during the summer months, from the first of June to the end of September. It cannot handle jets, as its 8,400-foot runway is too short. As the primary air service facility for Yellowstone National Park, approximately 15,000 commercial passengers were handled by the airport in 1972.

The presence of a winter resort at the Ski Yellowstone site could very definitely alter the use characteristics of the airport. In the opinion of a local airline official, the airport could be maintained all year if the potential market were present. Since one ski area (Big Sky) already is in operation in the Yellowstone Airport region, the addition of another winter facility could possibly provide the necessary winter market. Winter operation of the airport would, in addition to providing increased business for West Yellowstone, serve as a relief for any possible pressure on the Gallatin Canyon Corridor.

COMMUNITY FACILITIES AND INSTITUTIONS

The major population center in the vicinity of the proposed Ski Yellowstone development is the town of West Yellowstone, incorporated in 1966, and located 12 miles from the development site. The permanent population numbers around 750. In the summer, this population swells to approximately three times this size, and absorbs up to 2,500 overnight visitors in addition to the permanent residents. For the residents, the town's two summer stock theatres, plus a movie theatre open during the summer and a portion of the winter, are available for entertainment. The town also contains a museum, a small heated public pool, a tennis court, and horseback riding, bicycling, and snowmobiling facilities, which may be utilized by area residents. A convention center is scheduled to open this fall.

West Yellowstone has an elementary school and a high school. At this time, school bus service is provided as far as the Kirkwood Ridge development, past the proposed Ski Yellowstone site, and could potentially be extended to the Madison Valley. A kindergarten program is scheduled to start in 1974. At the present time, school enrollment consists of 190 students as follows: elementary grades (1-8), 140 students; high school grades (9-12), 50 students. The school system could absorb an estimated 50% more elementary pupils and 100% more high school pupils. The system provides an athletic program which includes

football, basketball, swimming, alpine and nordic skiing, and a drill team, and offers music, art, small engine mechanic shop, home economics, chefs classes, market studies, advertising, wholesale and retailing, and French classes. The City Council would welcome use of the town's school facilities by the families of Ski Yellowstone personnel.

The community environment of West Yellowstone has been characterized by a great influx of tourists, attracted by Yellowstone National Park, in the summer, and extremely quiet winters, broken only by snowmobile rallies. The airport does not operate in the winter, some motels, theatres, etc. close down, and the number of people in town drops to 1/20 of its summer peak level. The town owes its continued existence to the presence of the West Entrance of Yellowstone National Park, which is located less than a mile east of town. For the last few years, the West Entrance has been used by approximately 650,000 automobile visitors (about 30% of the Park's total) yearly, and by around 80% of the over-snow vehicles entering the park (about 22,000 in 1972). All of these travelers must pass through West Yellowstone.

Although the increasing popularity of oversnow vehicles in Yellowstone National Park and in the West Yellowstone area is beginning to provide the town with some winter activity, the great disparity which exists between summer and winter character of the town has not diminished to any significant extent. The presence of a major winter resort development as close to West Yellowstone as the Ski Yellowstone site would go a long way toward achieving winter activity levels in the direction of those now found only in the summer season and, in so doing, provide greater economic stability. More motels, restaurants, gift shops, theatres, etc. could remain open through the winter, and winter visitors could provide the additional market potential necessary in order for the airport to extend its services to include the winter season. Facilities, services, and utilities already exist which are able to handle the extremely high peak population loads occurring now during the summer, so there should be no problem accommodating an increase in the present very low winter levels. The economy of the town would definitely benefit from a levelling off of summer/winter extremes, and more of the town's residents would be able to obtain year-round employment. (At the present time, approximately 200 people are employed during the winter, with about 250 unemployed.)

In the opinion of the Forest Service in 1967, "West Yellowstone has the snow, the terrain, the accommodations, the atmosphere, and if Yellowstone Airport opens, the transportation to make this community a major winter sports center. The winter operation of the airport, together with a thriving ski and snowmobile business, would put the town on a year-round basis... The development of winter sports on a large scale can do more for the West Yellowstone economy than any other single factor."

URBAN SERVICES

Morrison-Maierle, Inc.
and Beardsley, Davis Assoc., Inc.

INTRODUCTION

Although the town of West Yellowstone is the nearest community to the site of the proposed Ski Yellowstone development, the development will probably not provide a direct impact on public services and utilities of the town. The ski resort development will be located at such a distance from West Yellowstone that it would be both technically and economically infeasible, in most cases, for the resort to attempt to utilize the town's services. As a result, Ski Yellowstone will be a predominantly self-contained system with respect to urban services. Indirect effects may be felt in the town, however, due to an increase in winter visitors attracted to the area by the ski resort.

WATER

The projected winter domestic water demand for Ski Yellowstone in 1985 is estimated to be approximately 422,000 gallons per day, or an average of 293 gallons per minute. Summer water demands for the resort are estimated at 384,000 gallons per day plus 269,000 gallons per day for sprinkling on average days and perhaps twice this amount on maximum days. A total of 922,000 gallons per day, or 640 gallons per minute, may be required on days of maximum use during the summer. In order to provide on maximum days of use a minimum of 250 gallons for each person housed at 100% occupancy, a maximum days supply for 5500 persons of 1,375,000 gallons, equalling an average flow of 955 gallons per minute, would be required.

The town of West Yellowstone has no municipal water system, obtaining its water from individual wells. A regional water system which included the Ski Yellowstone development would be impracticable because the distance between developments, and adverse characteristics of topography, would cause construction costs to be beyond realistic values.

Possible sources of water supply for Ski Yellowstone include springs which flow from Mt. Hebgen, Coal Creek, and wells. Well water represents a first choice for the supply.

SEWER

The State of Montana has adopted Water Quality Standards and a policy of nondegradation of existing high water quality. This nondegradation requirement will necessitate that the development dispose of its treated wastewater on land, since it would be impracticable to treat the wastewater to the level of water quality which exists in Hebgen Lake, particularly where nitrates are concerned. Sprinkler irrigation or percolation pond methods are under consideration

with sprinkler irrigation disposal of treated water on a farm crop, to be harvested and removed from the area, appearing to be the best alternative available at this time.

Because West Yellowstone's sanitary sewer system and sewage treatment plant, consisting of an activated sludge plant, polishing pond, and seepage disposal system, is capable on summer days of handling 10,000 or more visitors, plus town residents, the capacity is definitely available to handle potential increases in the present under-1,000-person levels treated in the winter. With respect to the Ski Yellowstone development, the 1972 amendments to the Federal Water Pollution Control Act encourage the use of regional wastewater treatment plants where practicable. Although in populous areas it has been found that a larger regional wastewater treatment plant can be operated more economically and provide better treatment than numerous smaller plants, a regional plant for Ski Yellowstone, West Yellowstone, and adjacent areas is not feasible or practical at this time. Distance and problems of topography would cause construction costs of a regional system to be prohibitive. Ski Yellowstone therefore plans to construct its own sewage collection and treatment system.

The development proposed is much too extensive to be served by septic tanks and drain fields for wastewater disposal. A sewage collection system will be required to carry the sewage to a central wastewater treatment facility. Daily sewage flows for the three phases of development are estimated for the peak periods of use as being 51,000 gallons in Phase I, 182,400 gallons in Phase II, and 338,000 gallons in Phase III. These flows are maximum daily flows expected at full occupancy during the three phases of development. The following are estimated seasonal and annual flows based on visitation projections as presented in the June 1973 report by Destination Resort Corporation:

	Phase I	Phase II	Phase III
Winter wastewater flow, gallons	8,456,000	18,485,000	31,000,000
Summer wastewater flow, gallons	7,356,000	16,536,000	29,220,000
Total annual wastewater flow, gallons	15,812,000	35,021,000	60,220,000
Annual daily average flow, gallons	43,500	96,000	165,000

The sanitary sewer collection system will be designed for peak flows, corresponding to the population at saturation density. The gravity collector, trunk and outfall lines will be sized to handle peak flows expected at the ultimate density plus an added allowance for expansion beyond these areas.

Prior to discharge of wastewater to ground disposal systems, the wastewater must be treated to an equivalent of "secondary" treatment, which is classified as removing a minimum of 85% of the Biochemical Oxygen Demand(BOD) and Suspended Solids (SS). Only minor amounts of phosphorous or nitrogen are removed by this process; thus the soils and vegetation in the land disposal process are utilized to remove these elements. Following secondary treatment, the wastewater must also be disinfected with chlorine prior to land disposal.

SOLID WASTE

Refuse collection in West Yellowstone is provided by a private contractor, who leases forty acres from the Forest Service, and is presently using ten of those acres. Solid wastes from the region are transported to this landfill disposal area, located about five miles north of the town, then compacted, and covered. According to the Montana State Department of Health, the landfill is being operated and maintained in a very satisfactory manner. The contractor's lease is for ten years, and no trouble is anticipated in gaining an extension. In the event that a renewal could not be obtained, however, solid waste might be trucked about thirty miles. At the present time, the contractor has sufficient equipment and space to service the Ski Yellowstone development, and this type of regional collection and disposal system seems to be the most feasible for the area. The landfill site is now being moderately used on a regional basis.

POWER AND COMMUNICATIONS

Power is supplied to the community by the Falls River Electric Co-op, which has the ability to supply a new development at Ski Yellowstone. The projected power needs of Ski Yellowstone are being taken into account by the Falls River Co-op in the preparation of their master plan. Phone service is supplied to the area by Mountain Bell, which foresees no problems in serving Ski Yellowstone. Microwave systems have been proposed to serve the project area.

POLICE AND FIRE PROTECTION

The town of West Yellowstone has a police force, consisting of five town police in summer and two in winter, plus one county deputy sheriff year-round. Fire protection is provided by a volunteer force, with two fire-trucks and ambulance service available. The Ski Yellowstone development plans to have its own security force, augmented by the county deputy sheriff, and plans to provide fire protection with its own fire-truck and volunteer fire organization.